

HEATHKIT[®] MANUAL

Auto-Ranging
Digital
Capacitance Meter
Model IT-2250



HEATH COMPANY • BENTON HARBOR, MICHIGAN

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INTRODUCTION

This Auto-Ranging Digital Capacitance Meter is a compact hand-held instrument that automatically measures the capacitance of any capacitor having a value that falls within the range of 0 pF to 199.9 mF (1999 Farad). The instrument will select the correct range and display the units of capacitance on the 3-1/2 digit liquid-crystal display. Light-emitting diodes indicate the correct units (pF, nF, μ F, or mF).

To operate this Meter, merely plug in the capacitor and press the POWER button. The value and the units will then be automatically displayed. The instrument is adequately protected by resistor, fuse, and diodes against possible overloads.

A key feature of this instrument (when compared to competitive units) is its ability to detect a "leaky" capacitor. A nomogram is provided so you can translate the readings you obtain, using the two Leakage switches, into approximate values of shunt or internal capacitor leakage resistance.

You can measure all types of capacitors: mica, glass, polystyrene, paper, Mylar*, electrolytic, air gap, etc.

For measuring capacitors that have a low operating voltage, the Meter supplies a low test voltage. This low test voltage is superimposed on a low bias voltage for measuring electrolytic capacitors. A remote extension cable is also provided so you can test capacitors that cannot be plugged directly into the Meter.

Standard capacitors supplied with this kit enable you to calibrate your Meter to the accuracies listed in the "Specifications" section of this Manual.

A 9-volt alkaline battery (not supplied) typically provides 4-10 hours of continuous operation. Battery condition is continuously monitored and a warning, "LOBAT," is displayed whenever the battery voltage drops to approximately 5 volts. You can also operate the Capacitance Meter continuously from line voltage using one of the optional Heathkit battery eliminators** available for this kit.

This Capacitance Meter is housed in a compact, lightweight case that features a pivoting stand to support the front at a convenient viewing angle. Its careful design will provide long, reliable performance for your laboratory, workbench, or portable applications.

*DuPont Registered Trademark

**Model PS-2350 for 120 VAC operation and Model PS-2450 for 240 VAC operation.

UNPACKING

DO NOT UNPACK ANY PART OF YOUR CAPACITANCE METER UNTIL YOU ARE INSTRUCTED TO DO SO.

The shipping carton for your Auto-Ranging Digital Capacitance Meter is divided into several small sections. These sections make up Packs 1 through 3 and the Final Pack as shown on the Pack Index Sheet. Do not unpack any of these parts until you are told to do so in a Parts List.

When you check parts against a "Parts List," return any part or group of parts packaged in a bag or envelope, with a part number on it, to its container after you identify it. Leave it there until you actually use it in a step. This will keep you from mixing up the parts and help you identify the parts when you need them.

Some parts, however, have been placed in a bag or envelope that is not marked with the actual part number, but with a packaging number that begins with the number "172-." These numbers are used for packaging purposes only and do not appear in the Manual "Parts Lists." Open each bag or envelope that is marked with only a "172-" packaging number to identify the parts it contains.

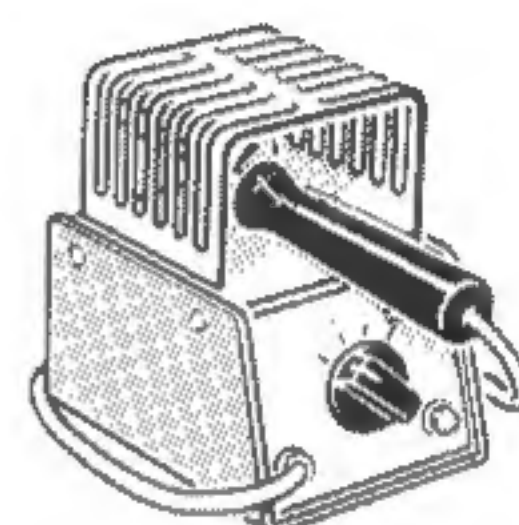
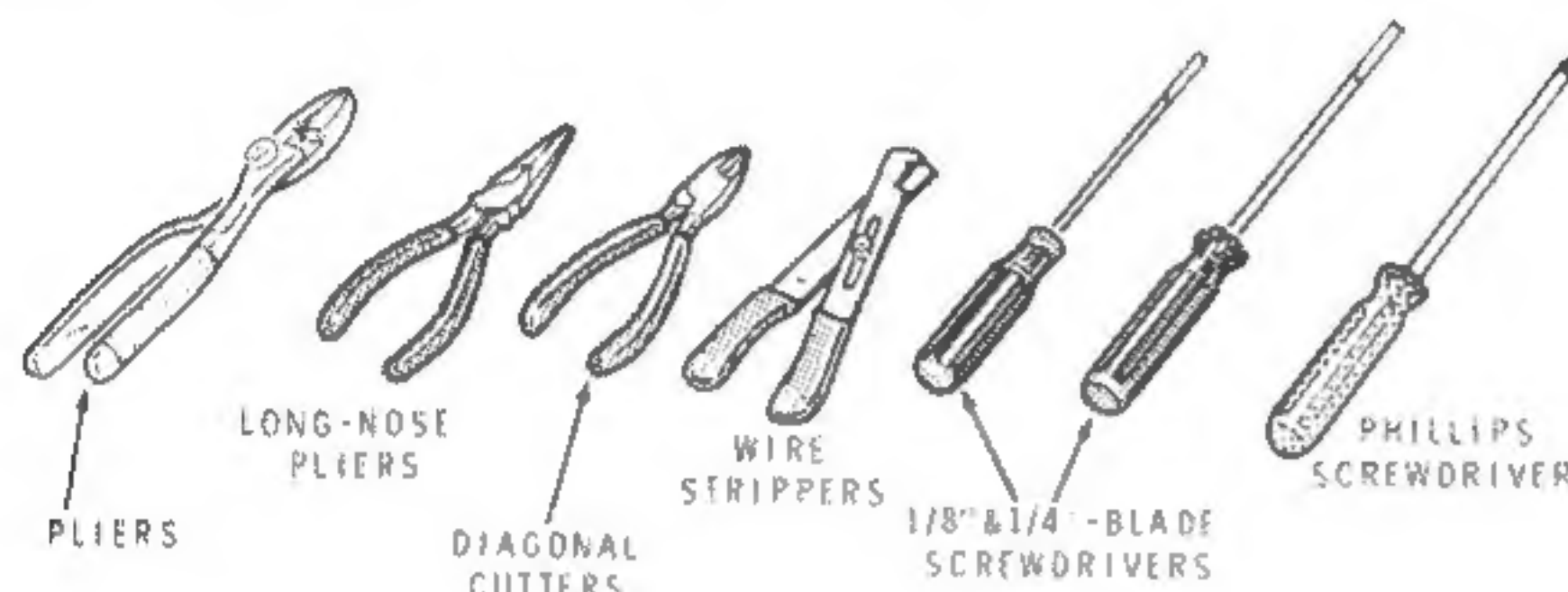
NOTE: Never use a "172-" packaging number if you must order a replacement part. Use only the part numbers listed in the Manual Parts Lists for this purpose.

Save all packaging material until you account for all the parts.

ASSEMBLY NOTES

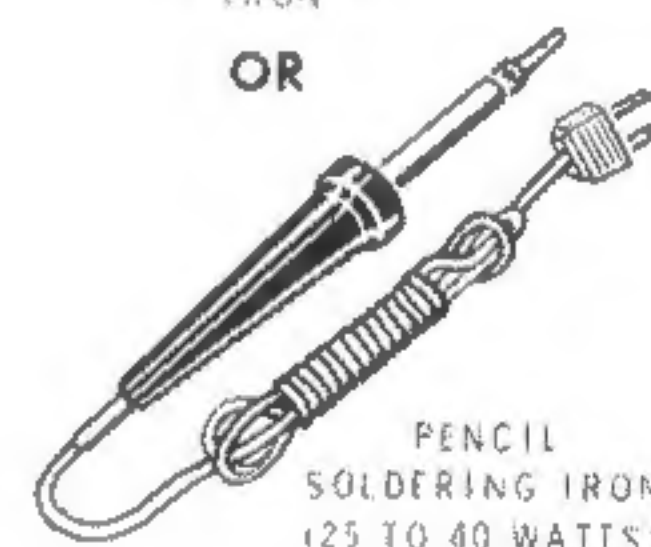
TOOLS

You will need these tools to assemble your kit.



HEATHKIT
SOLDERING
IRON

OR



PENCIL
SOLDERING IRON
(25 TO 40 WATTS)

OTHER HELPFUL TOOLS



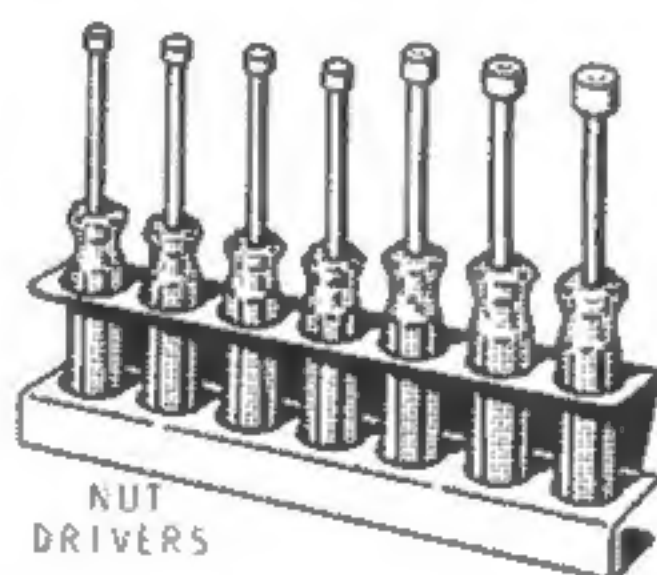
NUT STARTER
(MAY BE SUPPLIED
WITH KIT)



DESOLDERING
BULB*



DESOLDERING
BRAID*



NUT
DRIVERS

*TO REMOVE SOLDER FROM CIRCUIT CONNECTIONS

ASSEMBLY

1. Follow the instructions carefully. Read the entire step before you perform each operation.
2. The illustrations in the Manual are called Pictorials and Details. Pictorials show the overall operation for a group of assembly steps; Details generally illustrate a single step. When you are directed to refer to a certain Pictorial "for the following steps," continue using that Pictorial until you are referred to another Pictorial for another group of steps.
3. Most kits use a separate "Illustration Booklet" that contains illustrations (Pictorials, Details, etc.) that are too large for the Assembly Manual. Keep the "Illustration Booklet" with the Assembly Manual. The illustrations in it are arranged in Pictorial number sequence.
4. Position all parts as shown in the Pictorials.
5. Solder a part or a group of parts only when you are instructed to do so.

6. Each circuit part in an electronic kit has its own component number (R2, C4, etc.). Use these numbers when you want to identify the same part in the various sections of the Manual. These numbers, which are especially useful if a part has to be replaced, appear:
 - In the Parts List,
 - At the beginning of each step where a component is installed,
 - In some illustrations,
 - In the Schematic,
 - In the section at the rear of the Manual.
7. When you are instructed to cut something to a particular length, use the scales (rulers) provided at the bottom of the Manual pages.

SAFETY WARNING: Avoid eye injury when you cut off excessive lead lengths. Hold the leads so they cannot fly toward your eyes.

SOLDERING

Soldering is one of the most important operations you will perform while assembling your kit. A good solder connection will form an electrical connection between two parts, such as a component lead and a circuit board foil. A bad solder connection could prevent an otherwise well-assembled kit from operating properly.

It is easy to make a good solder connection if you follow a few simple rules:

1. Use the right type of soldering iron. A 25 to 40-watt pencil soldering iron with a 1/8" or 3/16" chisel or pyramid tip works best.
2. Keep the soldering iron tip clean. Wipe it often on a wet sponge or cloth; then apply solder to the tip to give the entire tip a wet look. This process is called tinning, and it will protect the tip and enable you to make good connections. When solder tends to "ball" or does not stick to the tip, the tip needs to be cleaned and retinned.

3. The circuit boards in this kit have foil on both sides. Note that the "component" (or lettered) side of each circuit board has the outline of each component screened on it. All components will be mounted on this side of the circuit board and soldered to the other side. Do **NOT** solder on the component side of the circuit boards unless you are instructed to do so.
4. Due to the nature of the foil pattern on the circuit boards, solder may be drawn through a circuit board hole from the foil side to the lettered side. **This is normal**, as many of the holes are "plated through" to connect the foils on both sides of the circuit board together. However, do not allow solder to flow into adjacent unused holes when you solder components to the foil.

NOTE: Always use rosin core, radio-type solder (60:40 or 50:50 tin-lead content) for all of the soldering in this kit. This is the type we have supplied with the parts. The Warranty will be void and we will not service any kit in which acid core solder or paste has been used.

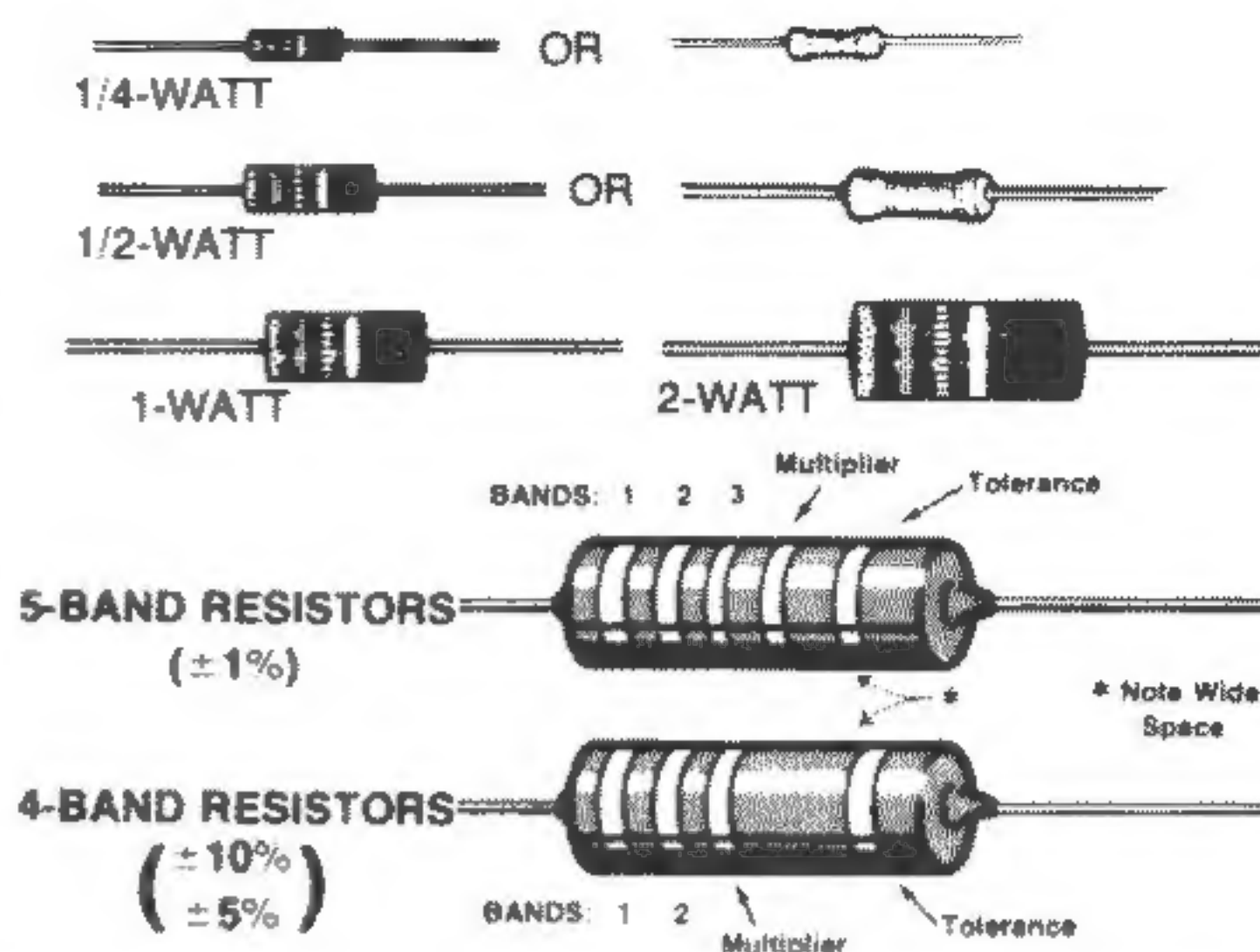
CONSTRUCTION HINTS

The following valuable hints will help you do a good assembly job.

- A. Take your time when you assemble the circuit boards. Work at a slow pace. Remember that accuracy is far more important than speed. Work with a good light to help reduce eye strain.
- B. When you perform the steps in the circuit board pictorials, identify each component **before** you install it. Then position it over its outline on the circuit board as shown in the Detail drawing.
- C. If you find it necessary to remove a component from the circuit board, use the desoldering braid supplied with this kit. Follow the directions on the package.

PARTS

Resistors are identified in Parts Lists and steps by their resistance value in Ω (ohms), $k\Omega$ (kilohms), or $M\Omega$ (megohms). They are usually identified by a color code and four or five color bands, where each color represents a number. These colors (except for the last band, which indicates a resistor's "tolerance") will be given in the steps in their proper order. Therefore, the following color code is given for information only. NOTE: Occasionally, a "precision" or "power" resistor may have the value stamped on it.



Band 1 1st Digit		Band 2 2nd Digit		Band 3 (if used) 3rd Digit		Multiplier		Resistance Tolerance	
Color	Digit	Color	Digit	Color	Digit	Color	Multiplier	Color	Tolerance
Black	0	Black	0	Black	0	Black	1	Silver	$\pm 10\%$
Brown	1	Brown	1	Brown	1	Brown	10	Gold	$\pm 5\%$
Red	2	Red	2	Red	2	Red	100	Brown	$\pm 1\%$
Orange	3	Orange	3	Orange	3	Orange	1,000		
Yellow	4	Yellow	4	Yellow	4	Yellow	10,000		
Green	5	Green	5	Green	5	Green	100,000		
Blue	6	Blue	6	Blue	6	Blue	1,000,000		
Violet	7	Violet	7	Violet	7	Silver	0.01		
Gray	8	Gray	8	Gray	8	Gold	0.1		
White	9	White	9	White	9				

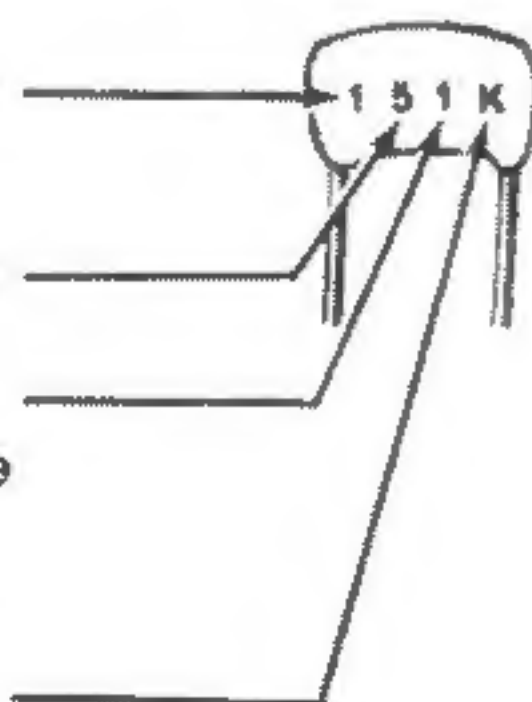
Capacitors will be called out by their capacitance value in μF (microfarads) or pF (picofarads) and type: ceramic, Mylar*, electrolytic, etc. Some capacitors may have their value printed in the following manner:

First digit of capacitor's value: 1

Second digit of capacitor's value: 5

Multiplier: Multiply the first & second digits by the proper value from the Multiplier Chart.

To find the tolerance of the capacitor, look up this letter in the Tolerance columns.



EXAMPLES:

$$151K = 15 \times 10 = 150 \text{ pF}$$

$$759 = 75 \times 0.1 = 7.5 \text{ pF}$$

NOTE: The letter "R" may be used at times to signify a decimal point: as in: 2R2 = 2.2 (pF or μF).

MULTIPLIER		TOLERANCE OF CAPACITOR		
FOR THE NUMBER:	MULTIPLY BY:	10 pF OR LESS	LETTER	OVER 10 pF
0	1	$\pm 0.1 \text{ pF}$	B	
1	10	$\pm 0.25 \text{ pF}$	C	
2	100	$\pm 0.5 \text{ pF}$	D	
3	1000	$\pm 1.0 \text{ pF}$	F	$\pm 1\%$
4	10,000	$\pm 2.0 \text{ pF}$	G	$\pm 2\%$
5	100,000		H	$\pm 3\%$
			J	$\pm 5\%$
8	0.01		K	$\pm 10\%$
9	0.1		M	$\pm 20\%$

MAIN CIRCUIT BOARD

PARTS LIST

Remove the parts from Pack 1. Check each part against the following list. The key numbers correspond to the numbers on the Main Circuit Board Parts Pictorial (Illustration Booklet, Page 1). Return any part that is packed in an individual envelope back to the envelope after you identify it. Keep these parts in the envelopes until they are called for in an assembly step. Do **NOT** throw away any packing material until you account for all the parts.

Some parts are marked with a "171-" or "172-" packaging number. These numbers are used for packaging purpose and do not appear in the Manual Parts List.

To order a replacement part, always include the **PART NUMBER**. Use the Parts Order Form furnished with this kit. If a Parts Order Form is not available, refer to "Replacement Parts" inside the rear cover of this Manual. For prices, refer to the separate "Heath Parts Price List."

KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
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RESISTORS

NOTES:

1. Resistors may be packed in more than one envelope. Open all of the resistor envelopes in this pack before you check the resistors against the following list.
2. All color-coded 1% resistors have five color bands (last band brown). This brown band is set apart from the other bands and is not called out below or in the steps.
3. The remaining resistors have four color bands and have a 5% tolerance unless otherwise noted. 5% tolerance is indicated by a gold fourth band. 10% tolerance is indicated by a silver fourth band. This fourth band (gold or silver) is not called out below or in the steps.

KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
------------	-------------------	------	-------------	----------------------

1/4-Watt, 1%

A1	6-8062-12	2	80.6 k Ω (gry-blk-blu-red), 100 PPM/°C	R210, R211
A1	6-1005-12	1	10 M Ω (brn-blk-blk-grn), 150 PPM/°C	R215

1/4-Watt, 5%

A1	6-102-12	1	1000 Ω (brn-blk-red)	R208
A1	6-103-12	10	10 k Ω (brn-blk-org)	R201, R202, R203, R206, R207, R209, R212, R213, R214, R216
A1	6-105-12	1	1 M Ω (brn-blk-grn)	R205

1/4-Watt, 10%

A1	1-88-12	1	10 M Ω (brn-blk-blu)	R204
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KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
---------	----------------	------	-------------	-------------------

CAPACITORS

Mica

B1	20-100	✓	1	30 pF	C208
B1	20-110	✓	1	75 pF	C204
B1	20-148	✗	2	100 pF	C210, C211
B1	20-114	✓	1	270 pF	C206
B1	20-115	✓	1	300 pF	C207

Ceramic

B2	21-5	✓	1	20 pF	C201
B2	21-192	✓	2	.1 μ F (104M)	C202, C205

Electrolytic

B3	25-931	✓	2	10 μ F, low leakage	C203, C209
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DIODES

C1	56-56	✓	7	1N4149	D201, D202, D203, D204, D205, D206, D207
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TRANSISTORS — INTEGRATED CIRCUITS (IC's)

NOTE: Transistors and integrated circuits are marked for identification in one of the following four ways:

1. Part number.
2. Type number. (On integrated circuits, use **only** those numbers and letters in **BOLD** print. Disregard any other numbers or letters.)
3. Part number and type number.
4. Part number with a type number other than the one shown.

D1	417-864	✗	2	MPSA05 transistor	Q202, Q203
D1	417-865	✓	1	MPSA55 transistor	Q201
D2	442-716	✗	1	LM330T IC	U201
D3	443-606	✗	2	4027 IC	U217, U219
D3	443-701	✗	1	4049 IC	U202
D3	443-706	✗	2	4071 IC	U208, U211
D3	443-713	✓	1	4028 IC	U206
D3	443-737	✗	2	4518 IC	U204, U205
D3	443-751	✗	3	4081 IC	U210, U212, U221
D3	443-784	✗	2	4070 IC	U209, U216
D3	443-813	✓	2	74LS90 IC	U203, U220
D3	443-838	✗	2	4174 or 340174 IC	U214, U215
D3	443-916	✓	1	4538 IC	U218
D3	443-950	✗	3	4072 IC	U207, U213, U222

KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
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MISCELLANEOUS

E1	75-782	1	PCB jack insulator*	
E2	75-801	3	Standoff insulator	
E3	404-238	1	3579.545 kHz crystal	Y201
E4	434-298	12	14-pin IC socket	
E4	434-299	9	16-pin IC socket	
E5	436-49	1	PCB jack	J201
E6	490-111	1	IC lifter	
	490-185	1	Package of desoldering braid	

Solder

PARTS FROM THE FINAL PACK

85-2447-1	1	Main circuit board
597-260	1	Parts Order Form (inside Manual)
	1	Assembly Manual (see Page 1 for part number).

Labels

F1	390-1767	1	Caution label**
F2	390-1768	1	Function label**
F3		1	Blue and white label**

BATTERY

You should purchase the following battery at this time for use in your kit.

One 9-volt transistor battery, NEDA #1604.

Representative manufacturers and their type numbers are:

Duracell #MN1604 (long life)
Eveready #216, P3
Burgess #2V6
Mallory #TR-146X (long life)
RCA #VS323
Hellekens #410
Varta #438
CEI #6F22
Ray-O-Vac #D1604-1 (long life)

*Set this part aside for use during the "General Assembly" section of your Manual.

**These labels are packed inside your Manual. Set them aside for use during the "Final Assembly" section of your Manual.

STEP-BY-STEP ASSEMBLY

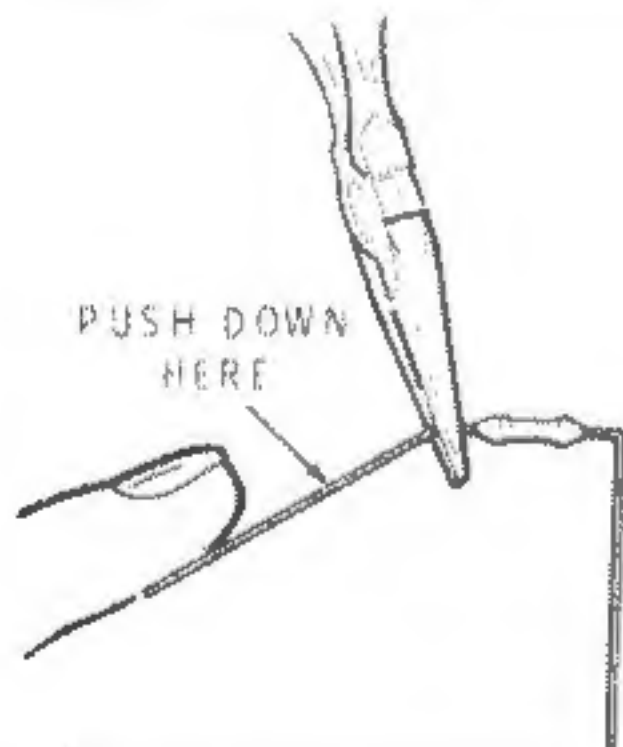
START

In the following steps, you will be given detailed instruction on how to install and solder the first part on the main circuit board. Read and perform each step carefully. Then use the same procedure whenever you install parts on a circuit board.

- (✓) Position the main circuit board as shown with the printed side up. Note that this circuit board has foil on both sides. Do NOT solder on the printed (component) side unless you are instructed to do so. The side of the circuit board opposite the printed side will be referred to as the foil side.

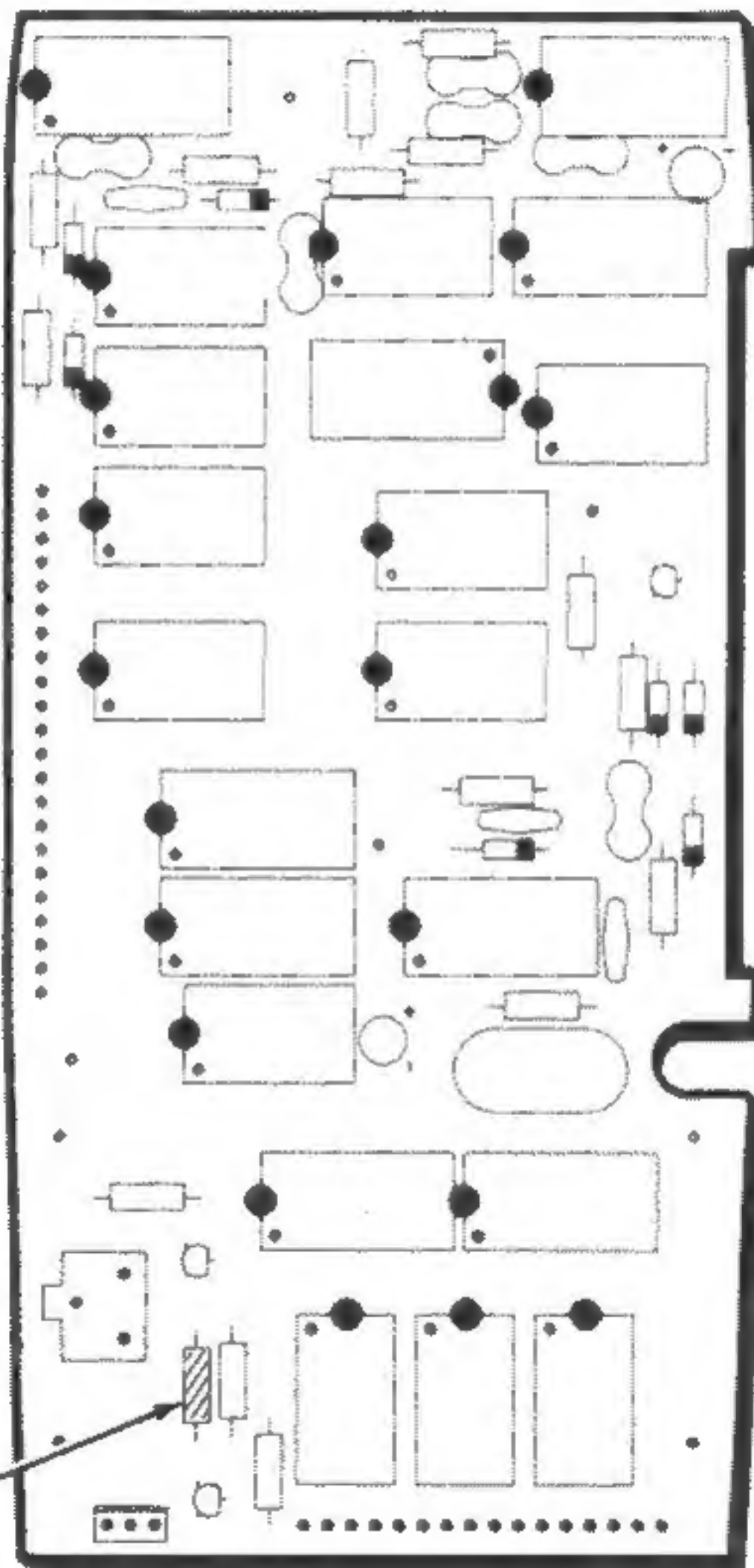
NOTE: When you install a component that has its value printed on it, position the value marking up, so it can be easily read. Diodes should be mounted with their type or part number up, if possible.

- (✓) Hold a 10 k Ω (brn-blk-org) resistor with long-nose pliers and bend the leads straight down to fit the hole spacing on the circuit board.



- (✓) R203: Push the leads through the holes at the indicated location on the circuit board. The end with color bands may be positioned either way.

- (✓) Press the resistor against the circuit board. Then bend the leads outward slightly to hold the resistor in place.

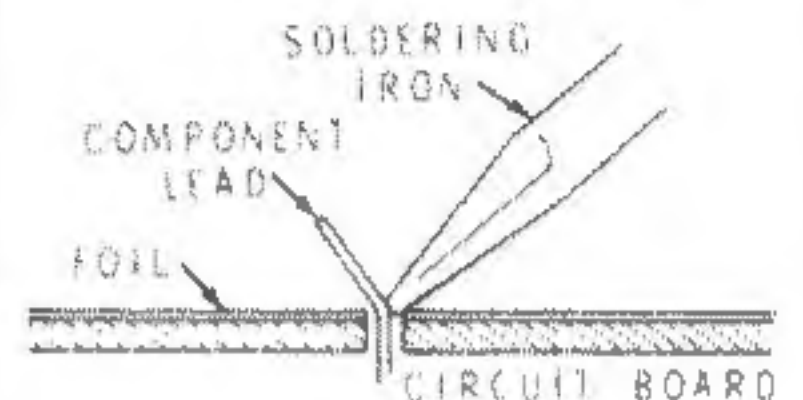


PICTORIAL 1-1

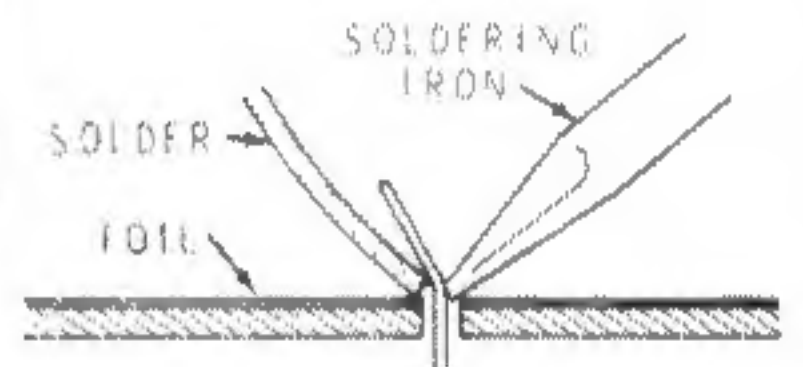
CONTINUE

- (✓) Turn the circuit board over and solder the resistor leads to the foil as follows:

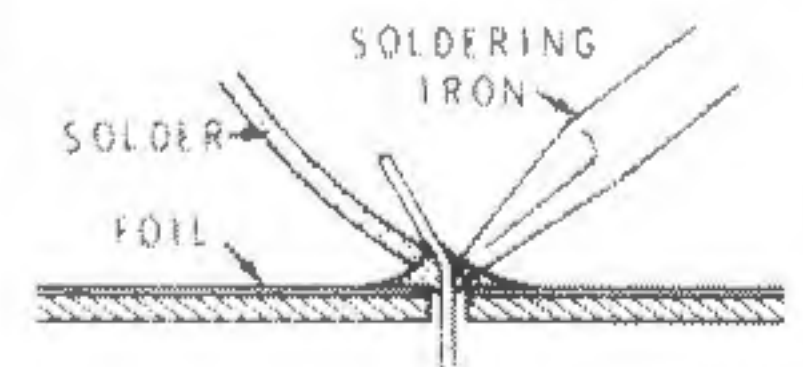
1. Push the soldering iron tip against both the lead and the circuit board foil. Heat both for two or three seconds.



2. Then apply solder to the other side of the connection. IMPORTANT: Let the heated lead and the circuit board foil melt the solder.



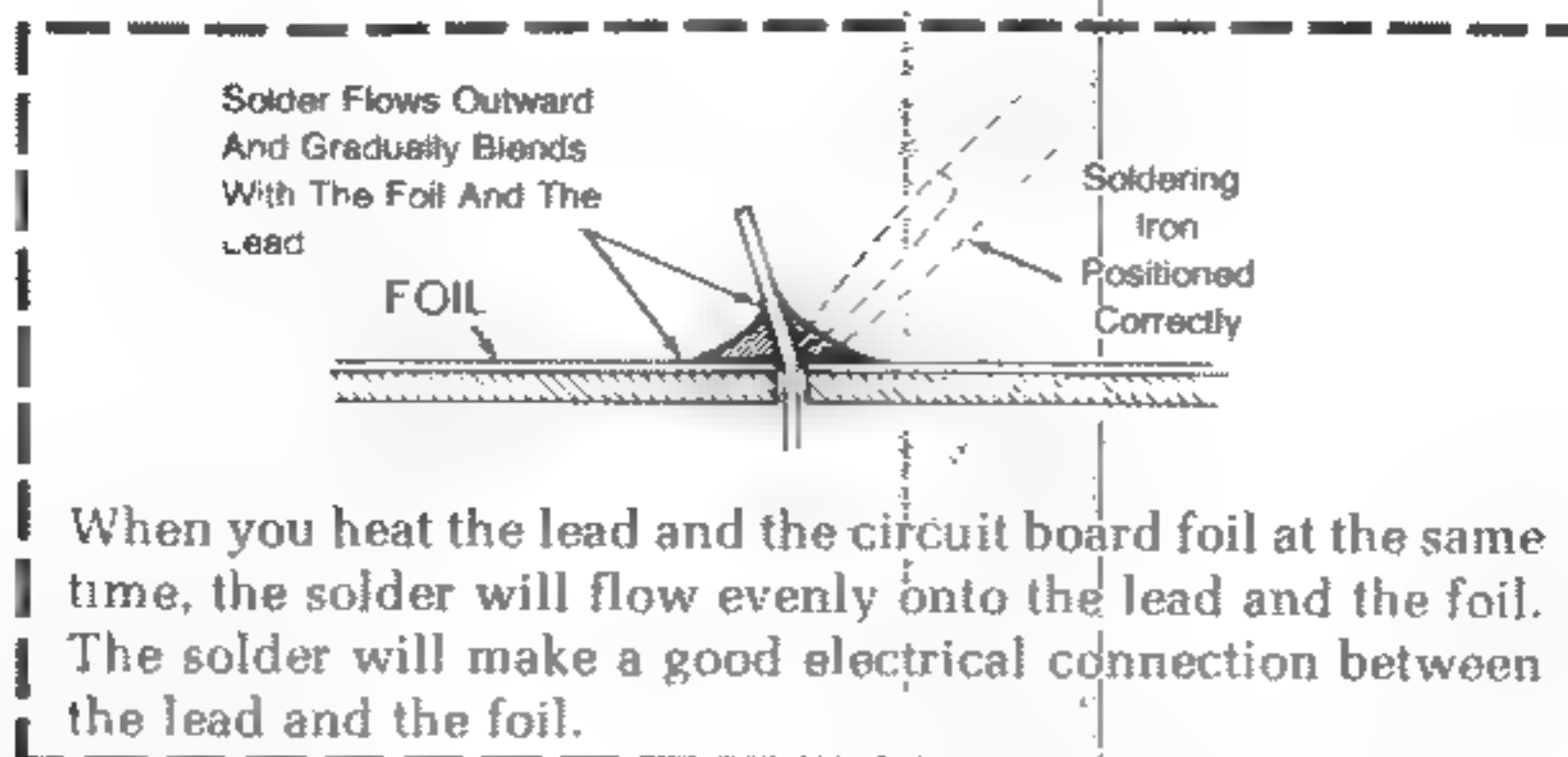
3. As the solder begins to melt, allow it to flow around the connection. Then remove the solder and iron and let the connection cool.



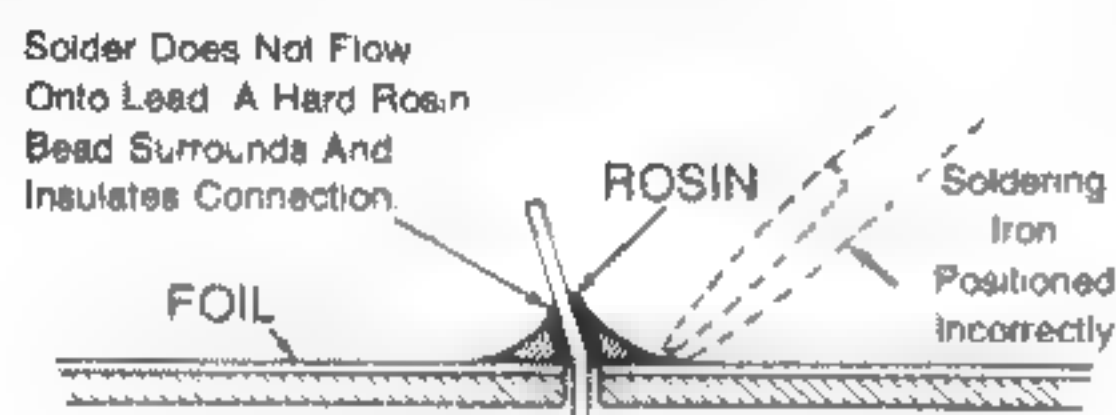
- (✓) Cut off the excess lead lengths close to the connection. WARNING: Clip the leads so the ends will not fly toward your eyes.

- (✓) Check each connection. Compare it to the illustrations on Page 11. After you have checked the solder connections, proceed with the assembly on Page 12. Use the same soldering procedure for each connection.

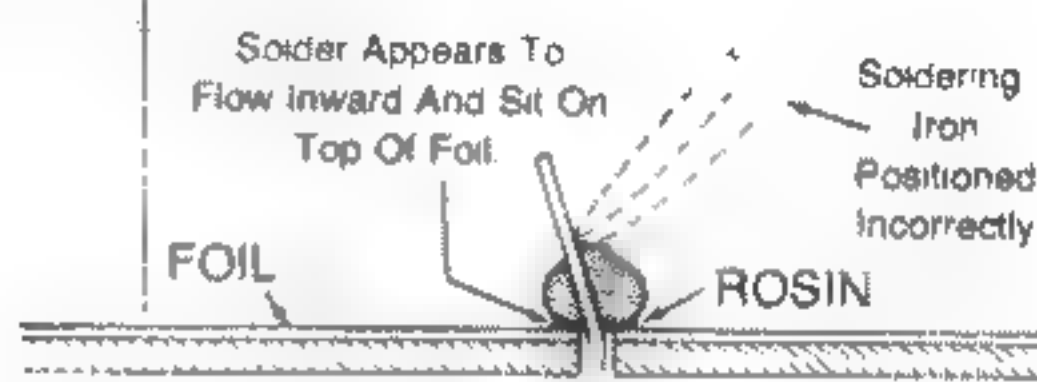
A GOOD SOLDER CONNECTION



POOR SOLDER CONNECTIONS



When the lead is not heated sufficiently, the solder will not flow onto the lead as shown above. To correct, reheat the connection and, if necessary, apply a small amount of additional solder to obtain a good connection.

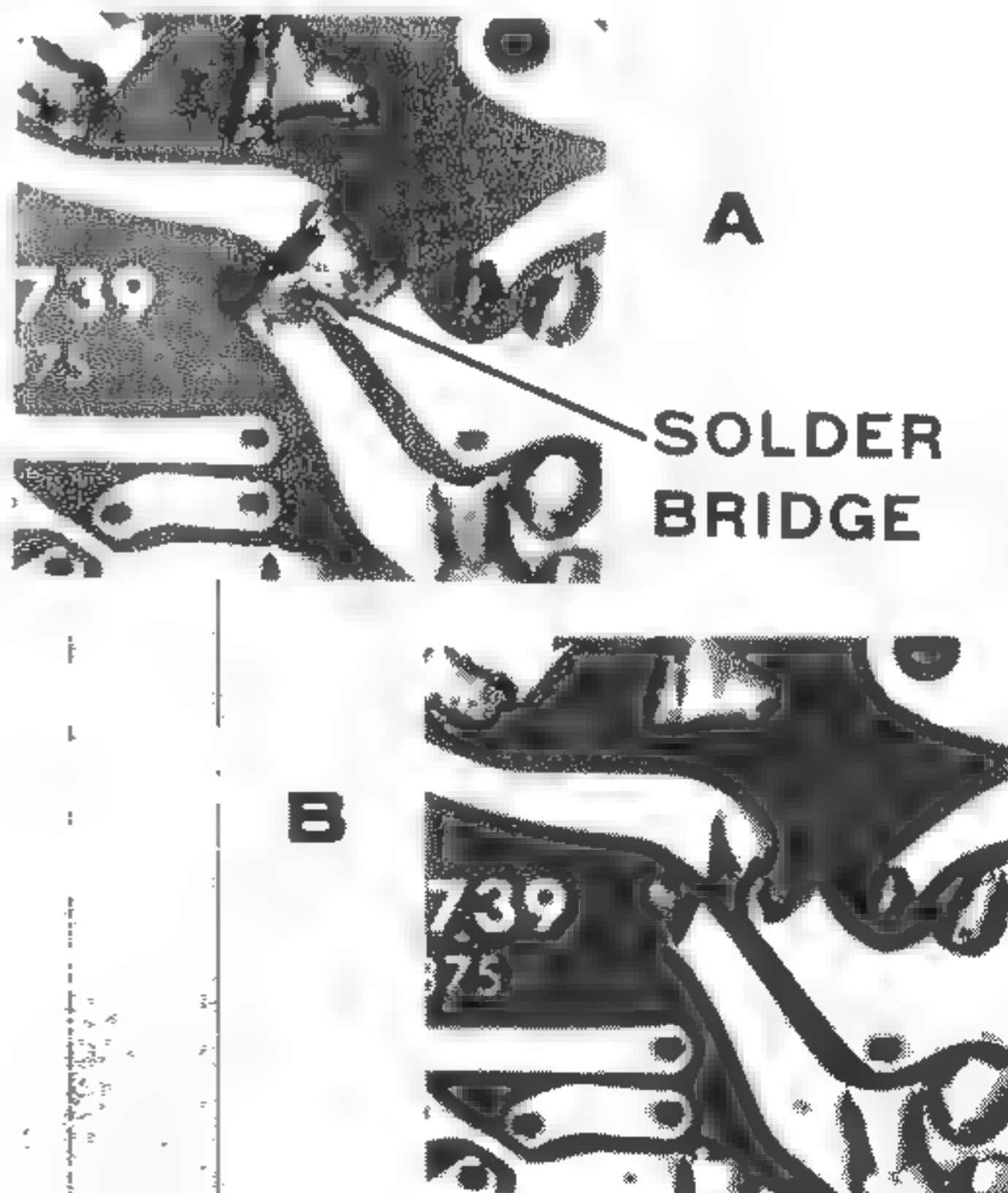


When the foil is not heated sufficiently the solder will blob on the circuit board as shown above. To correct, reheat the connection and, if necessary, apply a small amount of additional solder to obtain a good connection.

SOLDER BRIDGES

A solder bridge between two adjacent foils is shown in photograph A. Photograph B shows how the connection should appear. A solder bridge may occur if you accidentally touch an adjacent previously soldered connection, if you use too much solder, or if you "drag" the soldering iron across other foils as you remove it from the connection. A good rule to follow is: always take a good look at the foil area around each lead before you solder it. Then, when you solder the connection, make sure the solder remains in this area and does not bridge to another foil. This is especially important when the foils are small and close together. NOTE: It is alright for solder to bridge two connections on the same foil.

Use only enough solder to make a good connection, and lift the soldering iron straight up from the circuit board. If a solder bridge should develop, turn the circuit board foil side-down and heat the solder between connections. The excess solder will run onto the tip of the soldering iron, and this will remove the solder bridge. NOTE: The foil side of most circuit boards has a coating on it called "solder resist." This is a protective insulation to help prevent solder bridges.



START

NOTE Be sure you installed resistor R203 on Pictorial 1-1

(✓) R210 80.6 k Ω , 1% (gry blk blu-red)

(✓) R216 10 k Ω (brn-blk-org)

(✓) R209 10 k Ω (brn-blk-org)

(✓) R211 80.6 k Ω , 1% (gry-blk-blu-red)

NOTE Be sure to use the 1% resistor in the next step

(✓) R215 10 M Ω , 1% (brn-blk-blk-grn)

(✓) Solder the leads to the foil and cut off the excess lead lengths

(✓) R212 10 k Ω (brn-blk-org)

(✓) R213 10 k Ω (brn-blk-org)

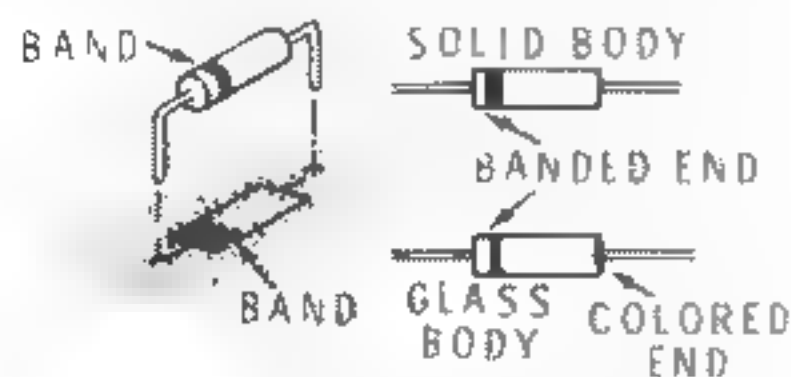
(✓) R207 10 k Ω (brn-blk-org)

(✓) R208 10 k Ω (brn-blk-org)

(✓) R205 1 M Ω (brn-blk-grn)

(✓) Solder the leads to the foil and cut off the excess lead lengths

NOTE When you install a diode, always match the band on the diode with the band mark on the circuit board. THE CIRCUIT WILL NOT WORK PROPERLY IF IT IS INSTALLED BACKWARDS. See Detail 1-2A



If your diode has a solid body, the band is clearly defined. If your diode has a glass body, do not mistake the colored end inside the diode for the banded end. Look for a band painted on the outside of the glass.

IMPORTANT THE BANDED END OF DIODES CAN BE MARKED IN A NUMBER OF WAYS



BANDED END

Detail 1-2A

CONTINUE

Install seven 1N4149 diodes (#56-56) at the following locations

(✓) D206

(✓) D205

(✓) D204

(✓) D203

(✓) D202

(✓) D201

(✓) D207

(✓) Solder the leads to the foil and cut off the excess lead lengths

(✓) R214 10 k Ω (brn-blk-org)

(✓) R204 10 M Ω 10% (brn-blk-blu)

(✓) R202 10 k Ω (brn-blk-org)

(✓) R201 10 k Ω (brn-blk-org)

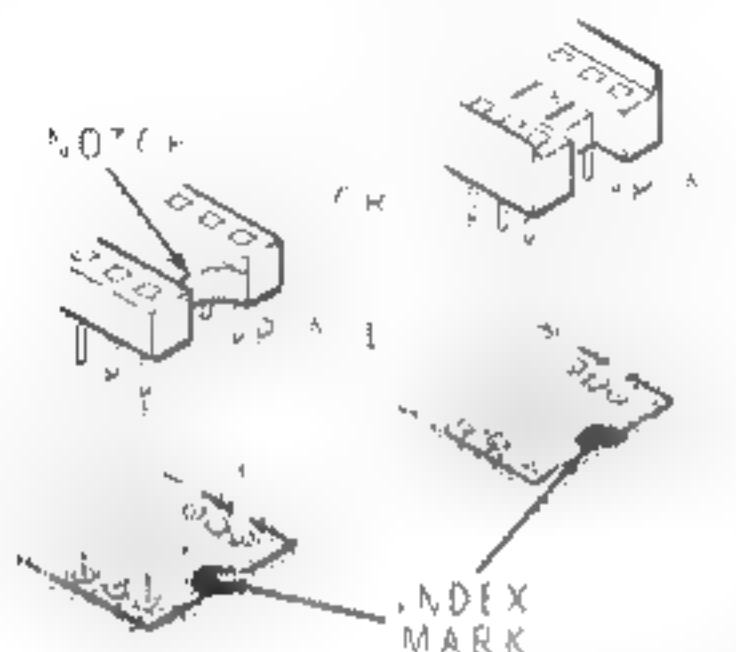
(✓) R208 1000 Ω (brn blk red)

(✓) Solder the leads to the foil and cut off the excess p.n. lengths

PICTORIAL 1-2

START

NOTE Be very careful when you install the 14 and 16-pin IC sockets as it is possible to place a 14-pin socket in a 16-pin socket location by mistake. Insert the socket pins into the holes. The index mark on the circuit board must still be visible after it is installed. Solder the pins to the foil as you install each socket and cut off any excess pin lengths.



() 16-pin IC socket at U218

Install four 14-pin IC sockets at:

() U221

() U211

() U208

() U212

Install two 16-pin IC sockets at

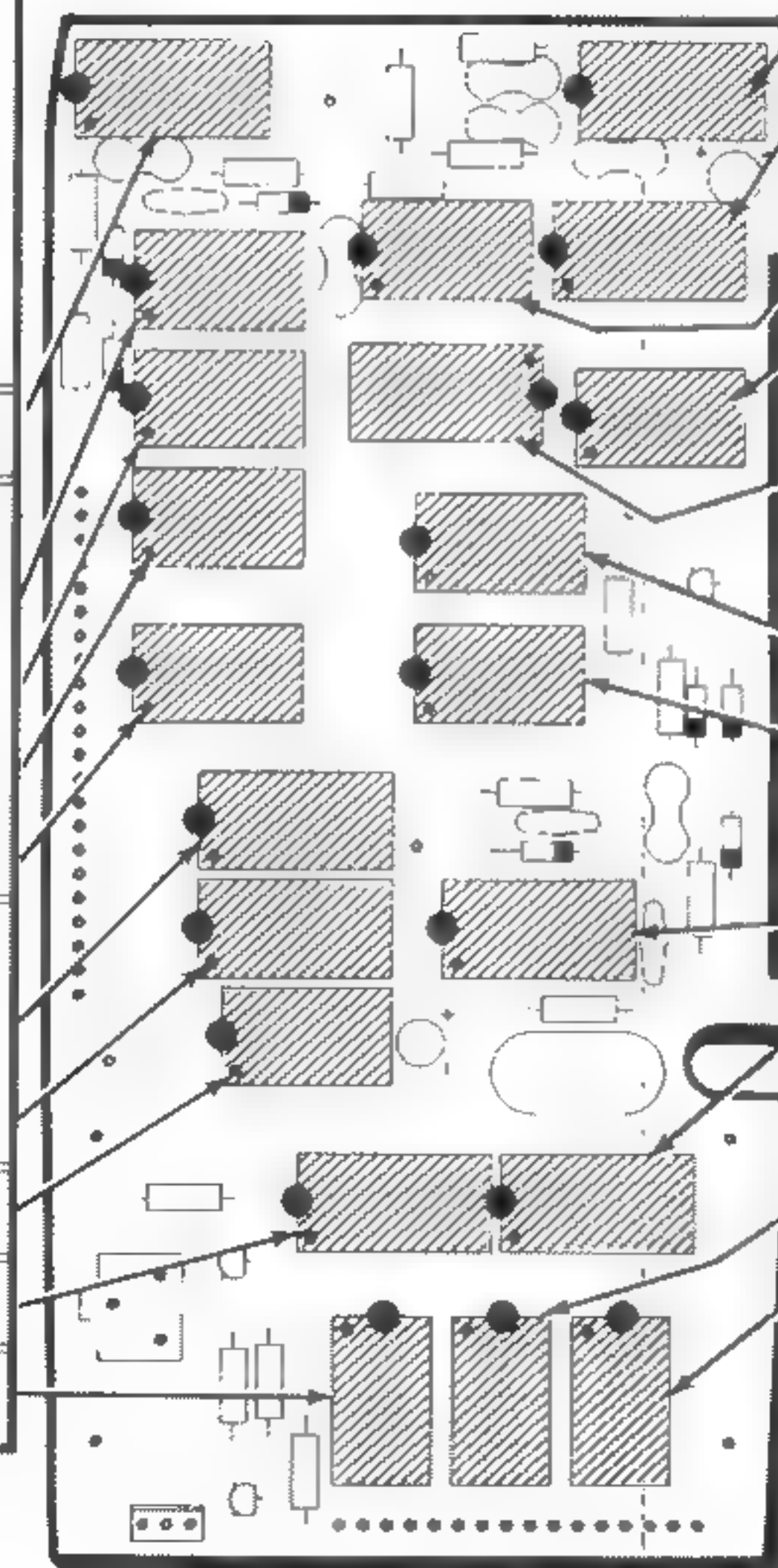
() U205

() U204

() 14-pin IC socket at U203

() 16-pin IC socket at U214

() 14 pin IC socket at U220



CONTINUE

Install two 16-pin IC sockets at

() U219

() U217

Install two 14-pin IC sockets at

() U210

() U222

() 16-pin IC socket at U206 NOTE: This socket is opposite to the other sockets

Install two 14-pin IC sockets at

() U207

() U213

Install two 16-pin IC sockets at

() U202

() U215

Install two 14-pin IC sockets at

() U209

() U216

Make sure you have soldered all of the pins to the circuit board foil and cut off the excess pin lengths

PICTORIAL 1-3

START ➔

NOTE: The circuit boards in this kit are very close together after the kit is assembled. Therefore, be sure to mount all parts down close to the circuit boards unless you are directed otherwise.

() C210 100 pF mica

() C208 30 pF mica

() C204 75 pF mica

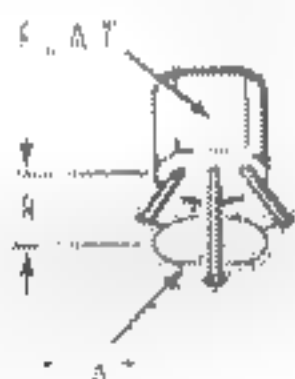
() C207 300 pF mica

() C205 1 μ F (104M) ceramic

(1) C211 100 pF mica

Solder the leads to the foil and cut off the excess lead lengths.

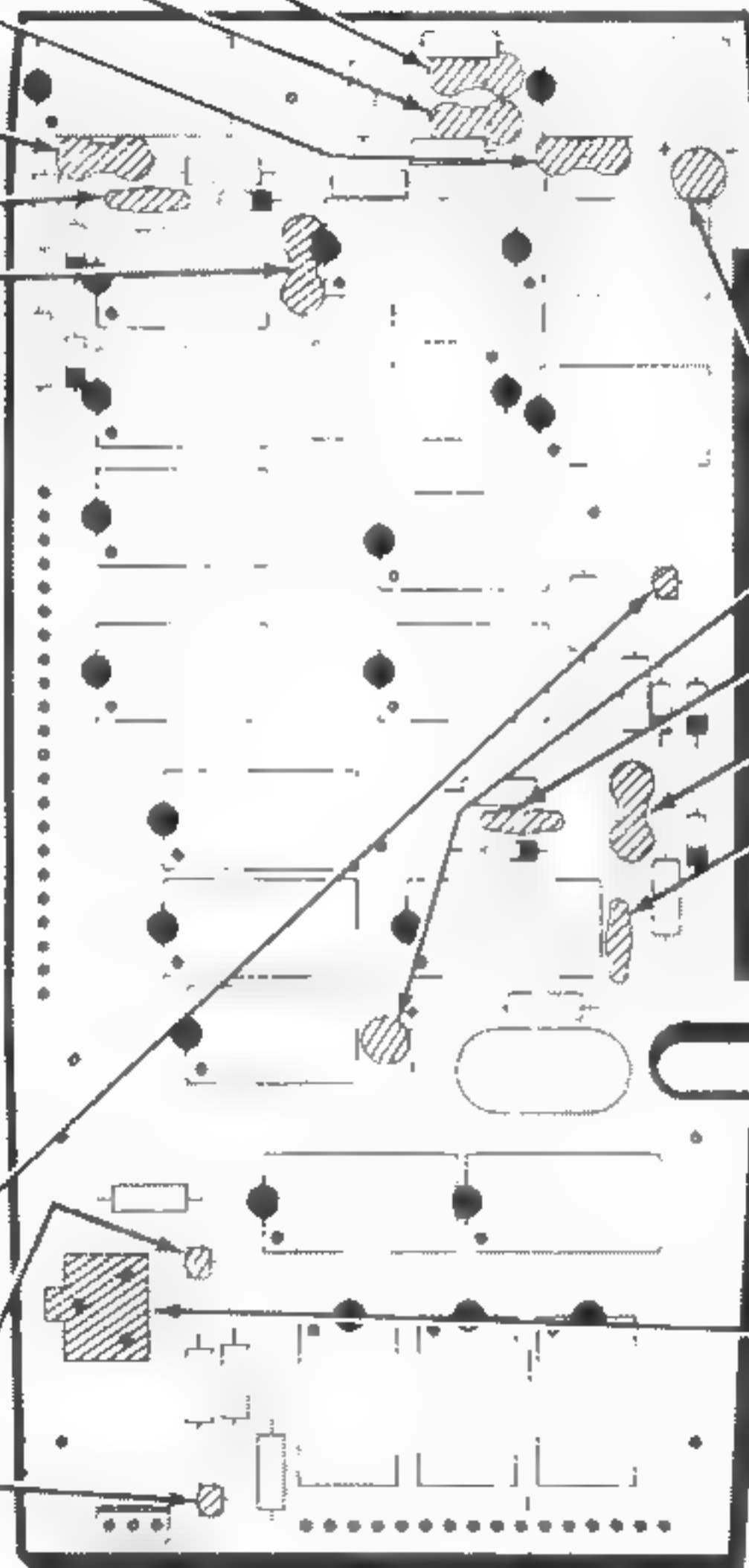
NOTE: When you install a transistor in each of the following steps, align its flat with the outline of the flat on the circuit board. Insert the leads into their correct holes. Position the transistor 1/8" above the circuit board. Then solder the leads to the foil and cut off the excess lead lengths.



() Q203 MPSA05 transistor (#417-864)

() Q202 MPSA05 transistor (#417-864)

() Q201 MPSA55 transistor (#417-865)



PICTORIAL 1-4

CONTINUE ➔

When you install an electrolytic capacitor, always match the positive (+) mark on the capacitor with the positive (+) mark on the circuit board OR match the negative (-) mark on the capacitor with the negative (-) mark on the circuit board. Be sure to form the leads of the capacitors to fit the circuit board holes.



(1) C209 10 μ F electrolytic

(1) C203 10 μ F electrolytic

(1) C202 1 μ F (104M) ceramic

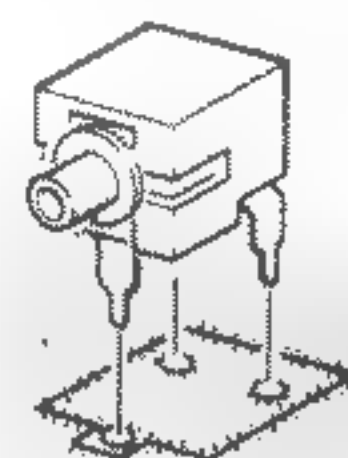
(1) C206 270 pF mica

(1) C201 20 pF ceramic

Bend capacitors C206 and C201 over toward the nearby edge of the circuit board.

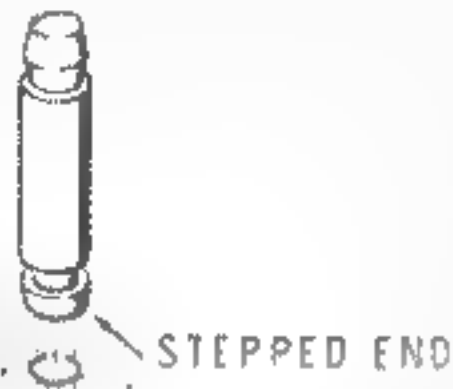
Solder the leads to the foil and cut off the excess lead lengths.

J201 PCB jack. Push the jack firmly down so it is properly seated against the circuit board. Then solder the lugs to the foil and cut off any excess lug lengths.



START →

NOTE: In the following steps, install standoff insulators at three locations on the component side of the circuit board. Place the stepped end of each insulator into the proper hole. If necessary, use a small nutdriver or similar object to drive the insulator into the hole.



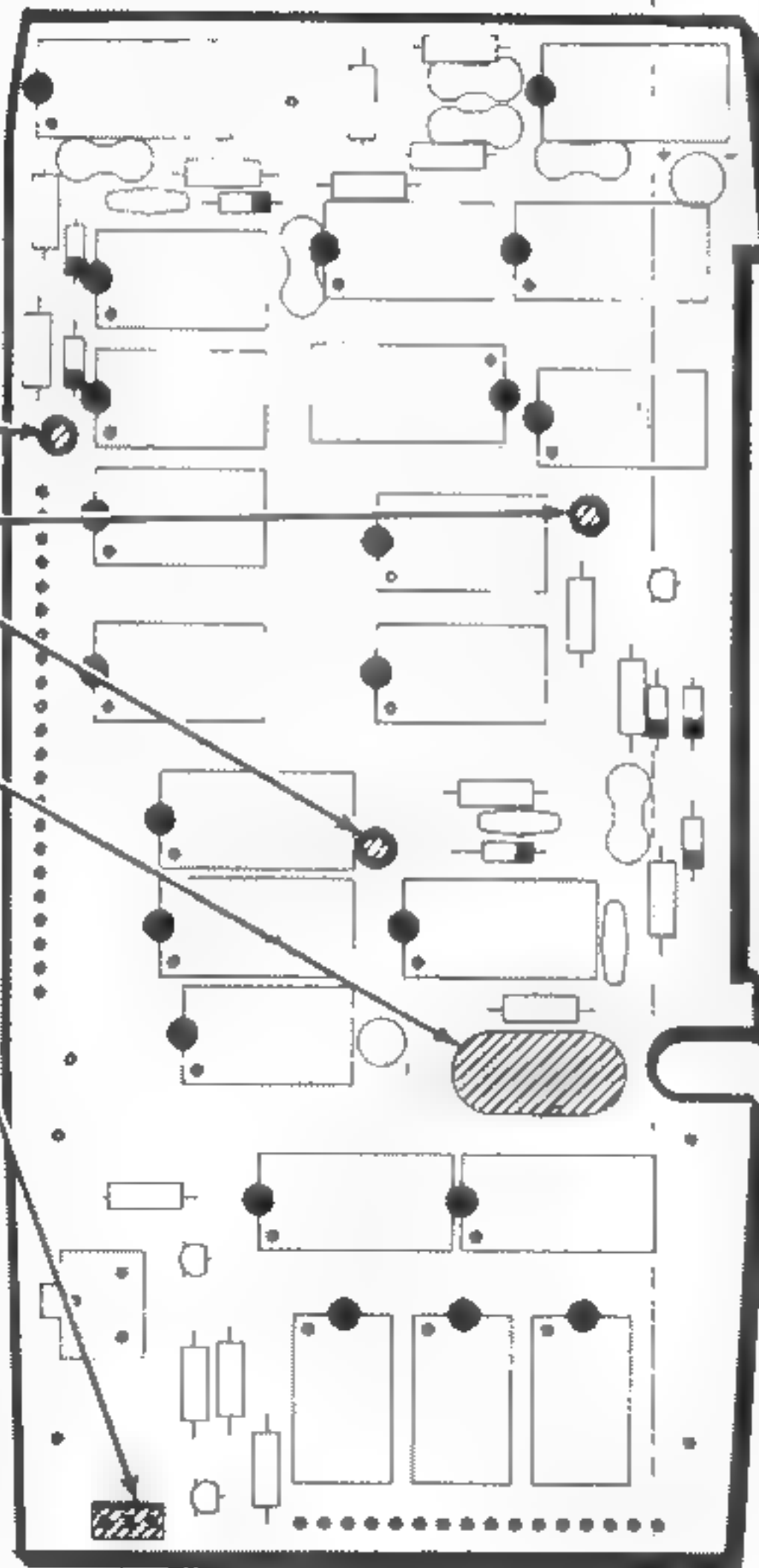
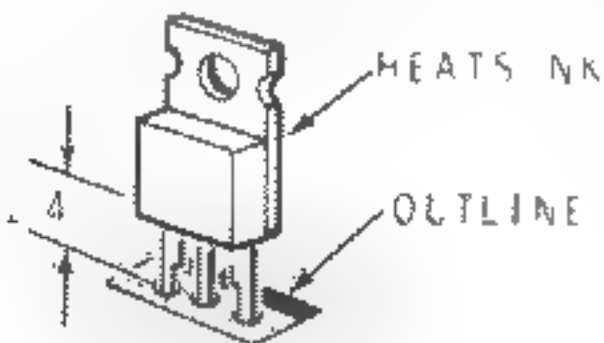
(✓) Standoff insulator.

(✓) Standoff insulator.

(✓) Standoff insulator.

(✓) Y201: 3579.545 kHz crystal. Solder the leads to the circuit board and cut off the excess lead lengths.

(✓) U201: LM330T IC (#442-716). Match the heat sink of the IC with the double line on the circuit board. Insert the IC leads into the corresponding holes. Solder each lead to the foil and cut off the excess lead lengths.



CONTINUE →

CIRCUIT BOARD CHECKOUT

Carefully inspect the foil side of the circuit board for the following most commonly made errors.

(✓) Unsoldered connections

(✓) Poor solder connections

(✓) Solder bridges between foil patterns.

(✓) Protruding leads which could touch together when the circuit board is installed later

Refer to the illustration where the parts were installed as you make the following visual checks

(✓) Electrolytic capacitors for the correct position of the positive (+) or negative (-) marked lead

(✓) Diodes for the proper type and installation

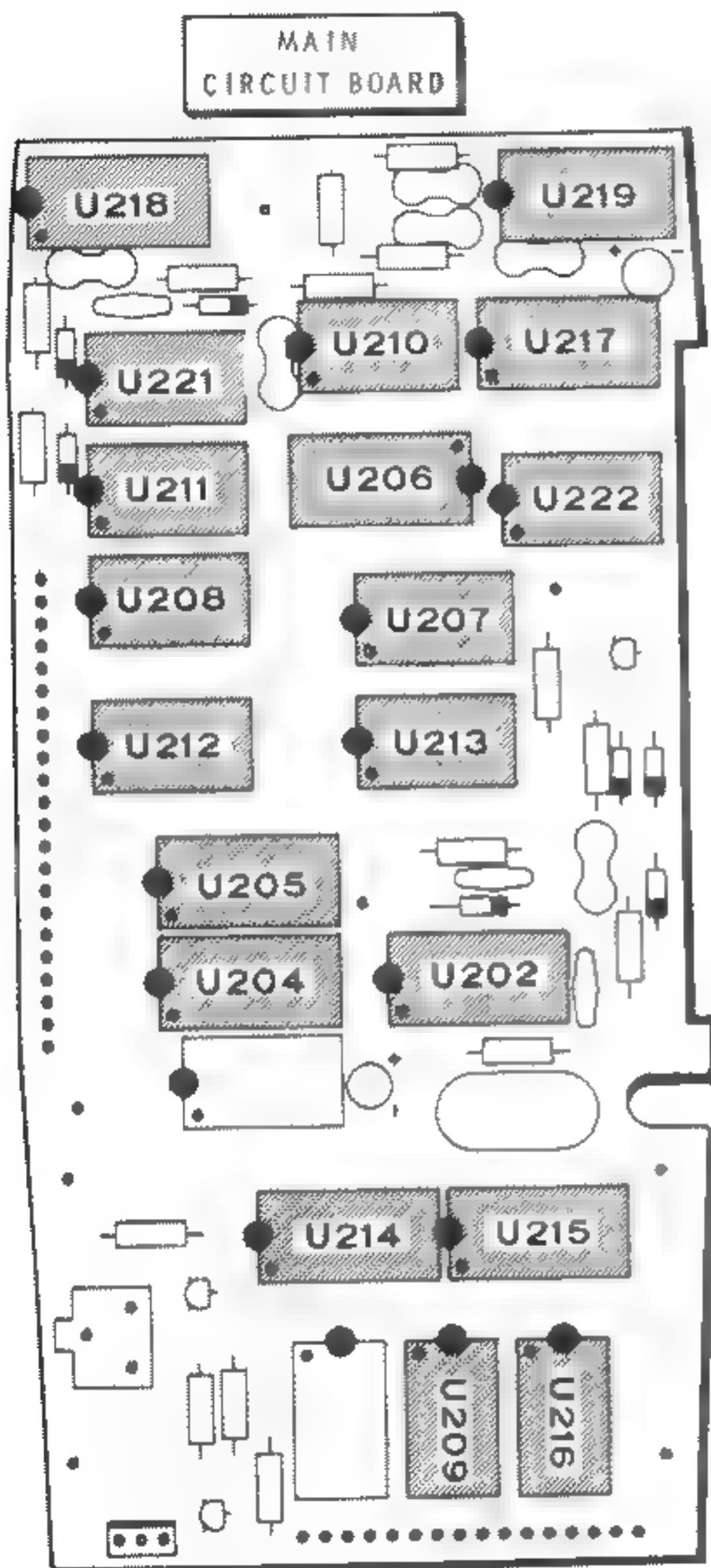
(✓) Transistors for the proper type and installation

(✓) U201 for the proper installation

PICTORIAL 1-5

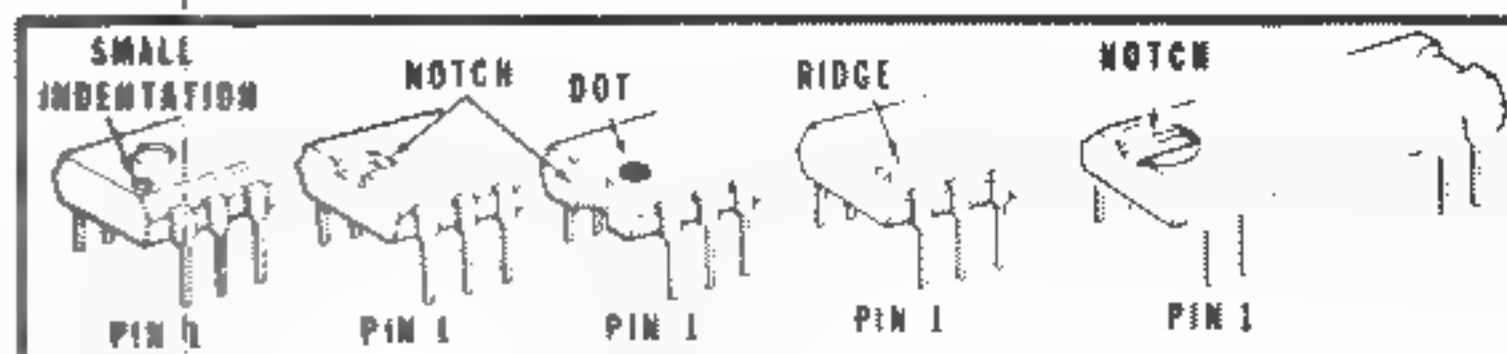
IC INSTALLATION

Refer to Pictorial 1-6 for the following steps.



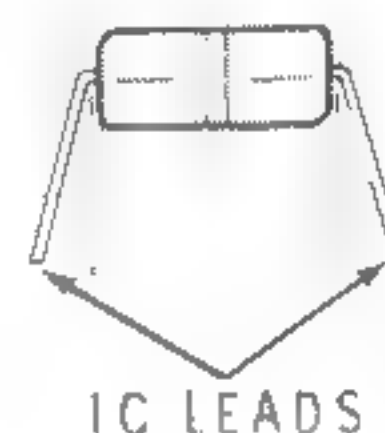
PICTORIAL 1-6

NOTE: Some integrated circuits are packed in conductive foam. These IC's are rugged and reliable components. However, normal static electricity discharged from your body through an IC pin to another object can damage the IC. To prevent the IC from becoming damaged, always hold the IC in one hand; then touch the other object (table, circuit board, etc.) with your other hand before you touch the object with the IC itself. Read all of the following information before you install the IC's.



Detail 1-6A

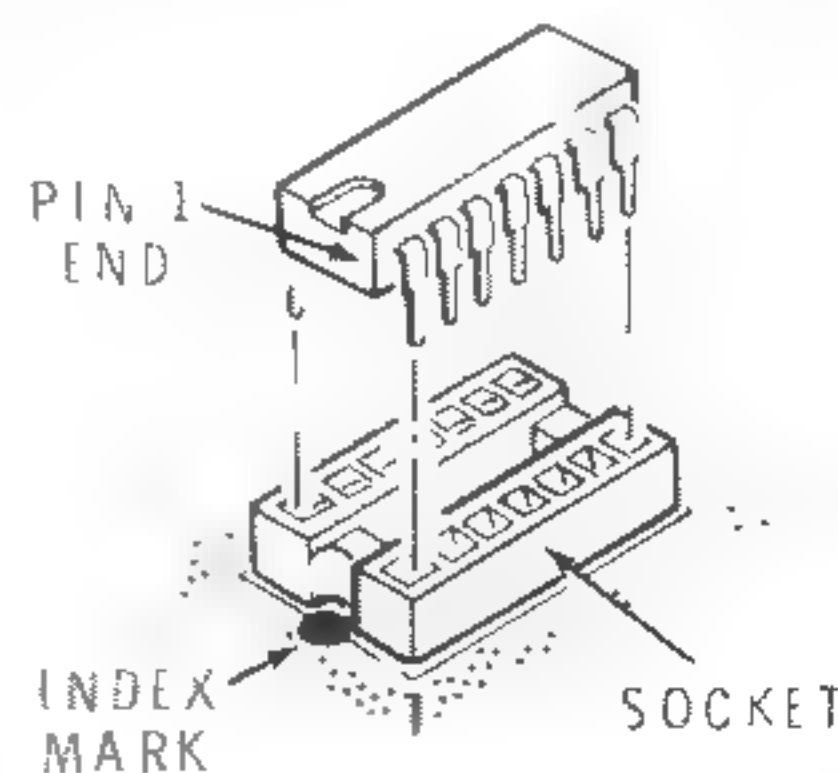
The pins on the IC's are bent out at an angle, so they do not line up with the holes in the IC socket. Do NOT try to install an IC without first bending the pins as described below. To do so may damage the IC pins or the socket, causing intermittent contact.



Before you install an IC, lay it down on its side as shown below and very carefully roll it toward the pins to bend the lower pins into line. Then turn the IC over and bend the pins on the other side in the same manner.



Refer to Detail 1-6A to identify the pin 1 end of each IC. Make sure that the pin 1 end is positioned over the index mark on the circuit board as shown below. Also, make sure that all of the pins are started into the socket. Then press the IC firmly into the socket. NOTE: An IC pin can become bent under the IC and it will appear as though it is correctly installed in the socket.

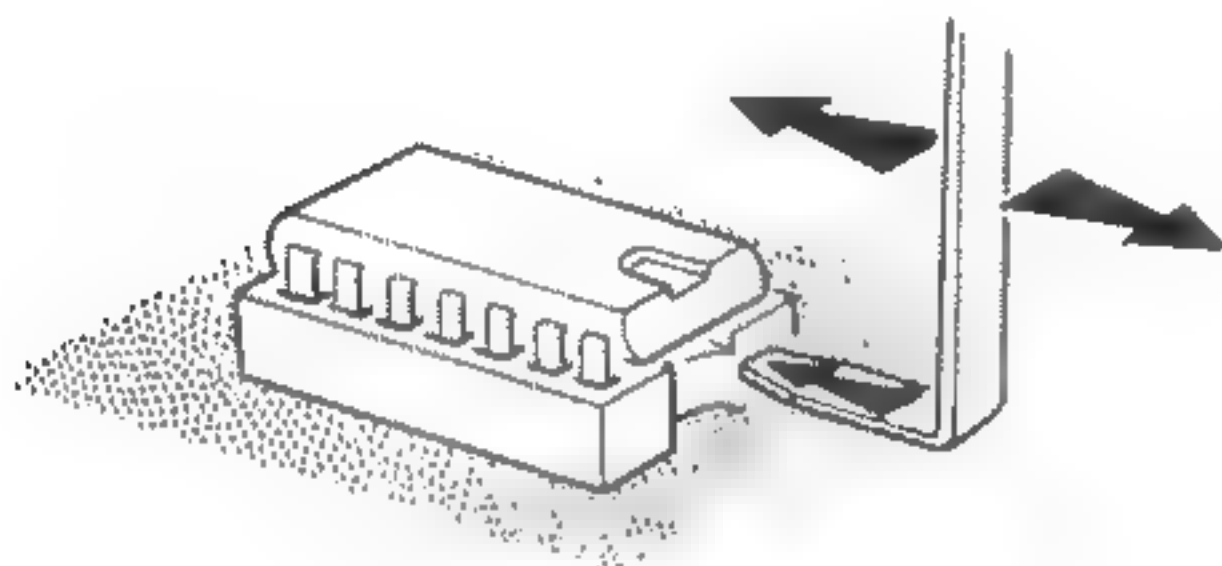


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NOTE: Some integrated circuits may have a 1 in front of the type numbers shown (14538 instead of 4538).

(✓) U218: 4538 IC (#443-916) at U218

NOTE: An IC lifter has been furnished so you can remove a dual-in-line IC from its socket if necessary.



Push the shorter end of the lifter in between the IC and the socket and rock the longer portion back and forth. Be very careful, as the IC pins bend very easily.

(✓) U219: 4027 IC (#443-606) at U219

(✓) U221: 4081 IC (#443-751) at U221.

() U210: 4081 IC (#443-751) at U210.

(✓) U217: 4027 IC (#443-606) at U217.

(✓) U211: 4071 IC (#443-706) at U211.

(✓) U206: 4028 IC (#443-713) at U206. NOTE: This IC is positioned opposite to the other IC's. Be sure to install it correctly.

(✓) U222: 4072 IC (#443-950) at U222

(✓) U208: 4071 IC (#443-706) at U208.

(✓) U207: 4072 IC (#443-950) at U207.

(✓) U212: 4081 IC (#443-751) at U212.

() U213: 4072 IC (#443-950) at U213.

(✓) U205: 4518 IC (#443-737) at U205.

(✓) U204: 4518 IC (#443-737) at U204.

(✓) U202: 4049 IC (#443-701) at U202.

(✓) U214: 4174 or 340174 IC (#443-836) at U214.

(✓) U215: 4174 or 340174 IC (#443-836) at U215

(✓) U209: 4070 IC (#443-784) at U209

(✓) U216: 4070 IC (#443-784) at U216.

NOTE: You will install IC's U203 and U220 later. Set these IC's aside temporarily.

This completes the "Step-by-Step Assembly" of the main circuit board. Set this circuit board assembly aside until it is called for in a step.

INPUT CIRCUIT BOARD

PARTS LIST

Remove the parts from Pack 2 and check each part against the following list. The key numbers correspond to the numbers on the "Input Circuit Board Parts Pictorial" (Illustration Booklet, Page 2).

To order a replacement part, always include the PART NUMBER. Use the Parts Order Form furnished with this kit. If a Parts Order Form is not available, refer to "Replacement Parts" inside the rear cover of this Manual. For prices, refer to the separate "Heath Parts Price List."

KEY No.	HEATH Part No.	QTY	DESCRIPTION	CIRCUIT Comp. No.
------------	-------------------	-----	-------------	----------------------

RESISTORS

NOTES.

- 1 Resistors may be packed in more than one envelope. Open all of the resistor envelopes in this pack before you check the resistors against the following list.
- 2 All color-coded 1% resistors have five color bands (last band brown). This brown band is set apart from the other bands and is not called out below or in the steps.
- 3 All color-coded 5% resistors have four color bands. 5% tolerance is indicated by a gold fourth band. This fourth band is not called out below or in the steps.

1/4-Watt, 1%

NOTE. The following resistors have a temperature coefficient (TC) of 100 parts per million per °C (100 PPM/°C).

A1	6-1009-12	1	10 Ω (brn-blk-blk-gold)	R115
A1	6-3019-12	1	30 1 Ω (org-blk-brn-gold)	R116
A1	6-1501-12	1	1500 Ω (brn-grn-blk-brn)	R122
A1	6-5001-12	3	5000 Ω (grn-blk-blk-brn)	R104, R105, R106
A1	6-1744-12	1	1 74 MΩ (brn-viol-yel-yel)	R128

KEY No.	HEATH Part No.	QTY	DESCRIPTION	CIRCUIT Comp. No.
------------	-------------------	-----	-------------	----------------------

1/4-Watt, 5%

A1	6-681-12	1	680 Ω (blu-gry-brn)	R145
A1	6-102-12	8	1000 Ω (brn-blk-red)	R108, R112, R119, R125, R130, R133, R142, R144
A1	6-472-12	8	4700 Ω (yel-viol-red)	R109, R113, R120, R126, R137, R138, R139, R140
A1	6-103-12	8	10 kΩ (brn-blk-org)	R103, R131, R132, R134, R135, R136, R141, R143
A1	6-473-12	8	47 kΩ (yel-viol-org)	R107, R110, R111, R114, R118, R121, R124, R127
A1	6-104-12	1	100 kΩ (brn-blk-yel)	R101

Other Resistors

A2	3-5-2	1	2.2 Ω, 2-watt, 10% wire-wound (red-red-gold)	R102
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KEY No	HEATH Part No	QTY	DESCRIPTION	CIRCUIT Comp. No.
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CONTROLS

A3	10-1167	1	100 Ω	R117
A3	10-1153	1	1000 Ω (1 k Ω)	R123
A3	10-1166	1	500 k Ω	R129

CAPACITORS

Mica

B1	20-118	1	15 pF	C101
B1	20-100	1	30 pF	C109
B1	20-110	1	75 pF	C107
B1	20-714	1	185 pF	C102B
B1	20-128	1	470 pF	C102A

Ceramic

B2	21-171	1	0.047 μ F (001M)	C110
B2	21-27	1	005 μ F	C108
B2	21-192	1	1 μ F (104M)	C106

Electrolytic

B3	25-931	3	10 μ F low leakage	C105, C111, C112
B3	25-918	1	100 μ F low leakage	C113

Other Capacitors

B4	26-166	1	1.3-5.4 pF air trimmer	C103
B5	31-65	1	15-60 pF ceramic trimmer	C104

DIODES

C1	56-56	5	1N4149	D104, D105, D106, D107, D108
C1	56-93	2	FD333	D101, D103
C1	56-619	1	1N4733A	D102

KEY No	HEATH Part No	QTY	DESCRIPTION	CIRCUIT Comp. No.
--------	---------------	-----	-------------	-------------------

TRANSISTORS — INTEGRATED CIRCUITS (IC's)

NOTE Transistors and integrated circuits are marked for identification in one of the following four ways

- 1 Part number
- 2 Type number. (On integrated circuits, use only those numbers and letter in **BOLD** print. Disregard any other numbers or letters.)
- 3 Part number and type number
- 4 Part number with a type number other than the one shown

D1	417-864	11	MPSA05 transistor	Q102 Q104
				Q106 Q108
				Q109 Q111
				Q112, Q113
				Q114, Q115
				Q116
D1	417-865	5	MPSA55 transistor	Q101, Q103, Q105 Q107
				Q110
D2	442-22	1	5741 IC	U102
D2	442-715	1	CA3130E IC	U101
D2	443-603	2	4011 IC	U103 U105
D2	443-751	1	4081 IC	U104

OTHER ELECTRONICS PARTS

E1	64-881	1	Switch w/locking action	SW101
E1	64-882	2	Switch w/momentary action	SW102 SW103
E2	260-24	2	Fuse clip	
E3	412-78	4	LED lamp	D109, D110, D111, D112
E4	421-65	1	1 4-ampere fuse	F101
E5	432-798	1	Battery connector	

HARDWARE

F1	250-1347	1	4-40 \times 3 32" setscrew
F2	250-1364	1	4-40 \times 3 16" flat head screw
F3	250-428	1	4-40 \times 1.4 flat head screw
F4	253-82	1	#4 flat washer
F5	253-43	1	#5 fiber flat washer
F6	254-41	1	#4 split lockwasher
F7	255-777	1	Metal spacer
F8	255-778	4	plastic spacer

*Set these parts aside for use in the "General Assembly" section of this Manual.

KEY No	HEATH Part No	QTY	DESCRIPTION
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SOCKETS — CLIPS

G1	434-230	2	8-pin IC socket
G1	434-298	3	14-pin IC socket
G2	436-53	4	Input contact

WIRE

344-90	6"	Black wire
344-92	6"	Red wire
344-128	6"	Orange wire
344-129	6"	Yellow wire
344-130	6"	Green wire

KEY No	HEATH Part No	QTY	DESCRIPTION
--------	---------------	-----	-------------

MISCELLANEOUS

H1	134-1112	1	22-wire ribbon cable
H2	256-48	2	Split rivet
H3	462-1125	1	Round knob
H4	490-23	1	Allen wrench
H5	490-203	1	Insertion tool

PARTS FROM THE FINAL PACK

J1	85-2537-1	1	Input circuit board
	206-1358	1	Shield

Important Construction Procedure

You must follow the procedure listed below whenever you handle the input circuit board in this kit. If you do not follow this procedure, the high impedance areas of the circuit board may be contaminated by salt and oil from your skin. When these areas become contaminated, your completed Capacitance Meter may not meet the listed specifications when you operate it in certain environments (high humidity conditions, etc.).

1. Wash your hands with soap and water before you handle the circuit board. Handle the circuit board only by its edges.
2. Avoid any excessive accumulation of rosin build-up whenever you solder a connection.

NOTE: The "Operational Tests" and "In Case of Difficulty" sections of this Manual will allow you to determine if the input circuit board has been contaminated. If necessary, you will be referred to a circuit board cleaning procedure.

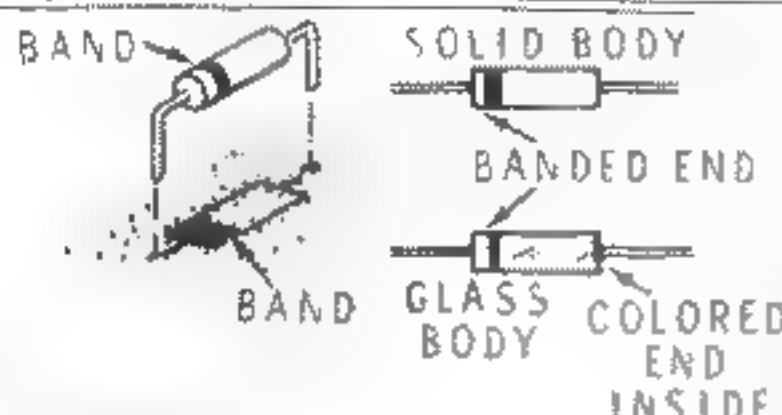


STEP-BY-STEP ASSEMBLY

START

REMEMBER The circuit boards will be very close together when the kit is assembled. Be sure to mount all parts close to the circuit board unless you are directed otherwise.

Position the input circuit board with the printed side up as shown.



ALWAYS POSITION THE BANDED END OF A DIODE AS SHOWN ON THE CIRCUIT BOARD.

D102: 1N4733A diode (#56-619).

D103: FD333 diode (#56-93).

D101: FD333 diode (#56-93).

R103: 10 k Ω (brn-blk-org).

R112: 1000 Ω (brn-blk-red).

Solder the leads to the foil and cut off the excess lead lengths.

R125: 1000 Ω (brn-blk-red).

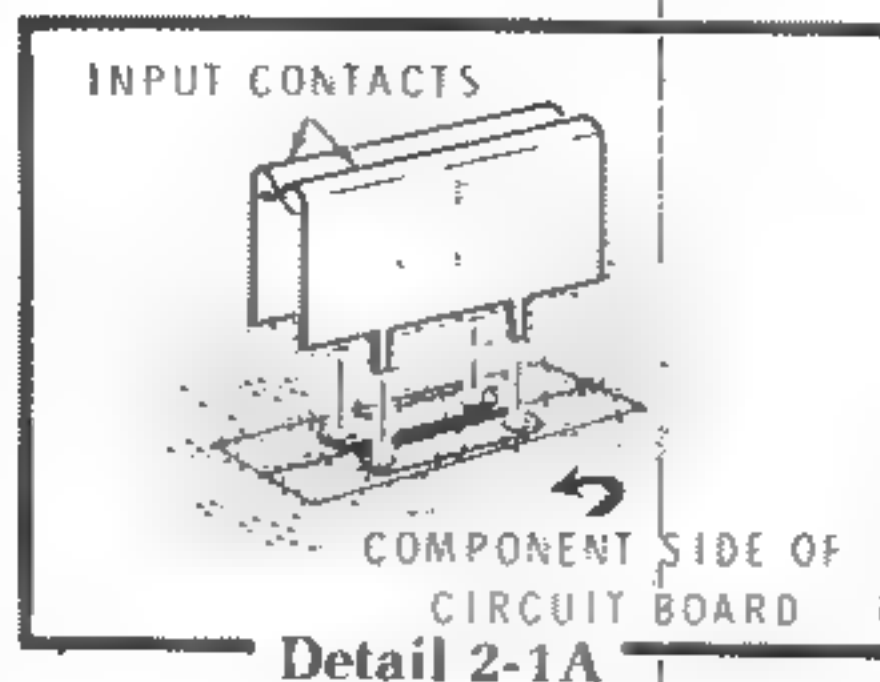
R119: 1000 Ω (brn-blk-red).

R130: 1000 Ω (brn-blk-red).

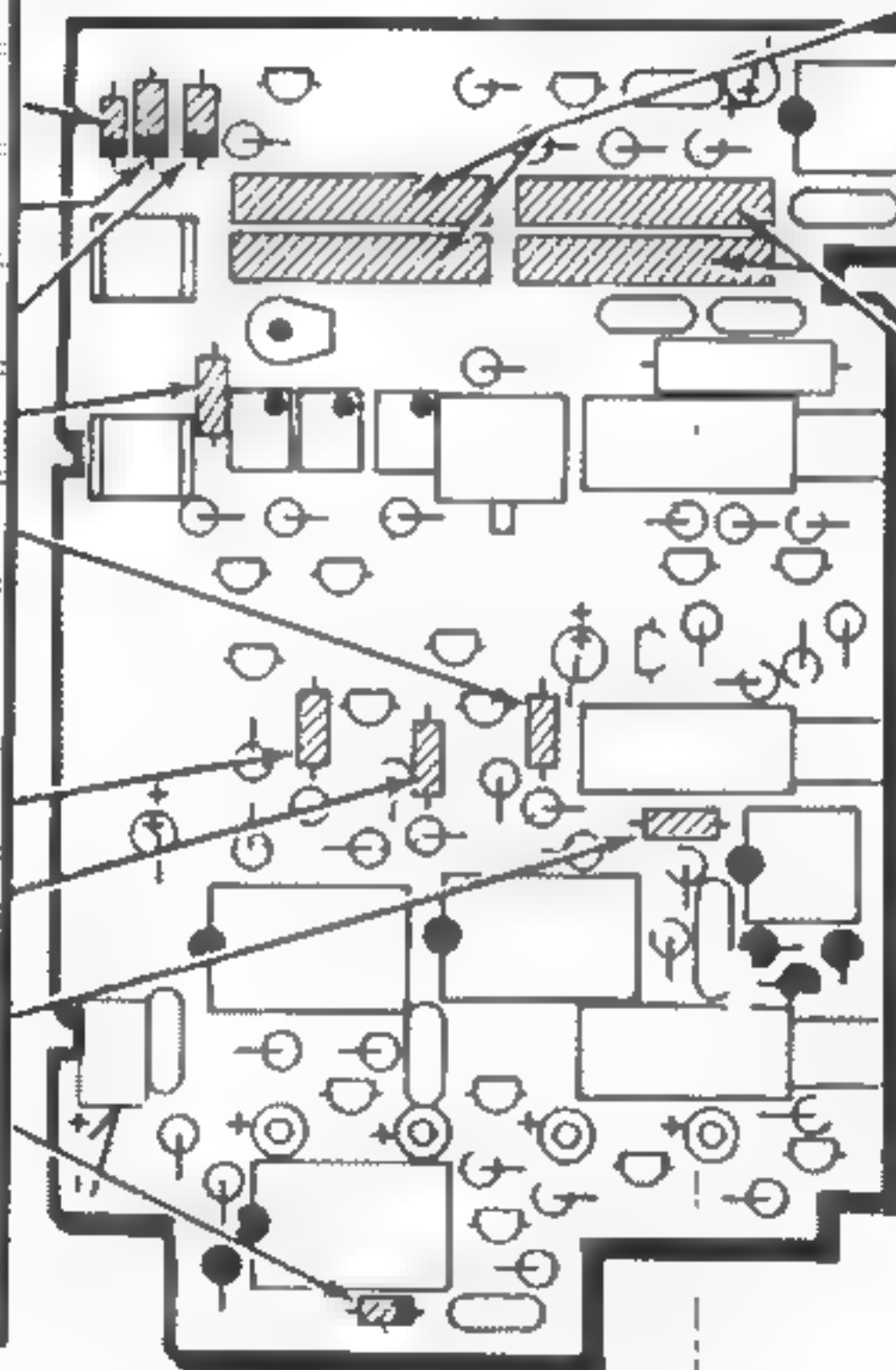
D108: 1N4149 diode (#56-56).

Solder the leads to the foil and cut off the excess lead lengths.

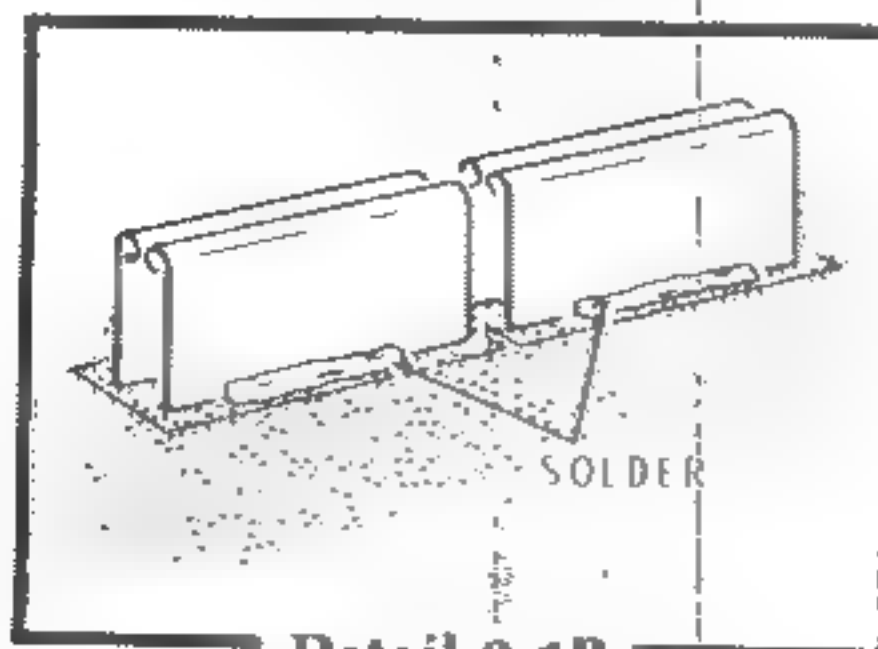
INPUT CONTACTS



Detail 2-1A



PICTORIAL 2-1



Detail 2-1B

CONTINUE

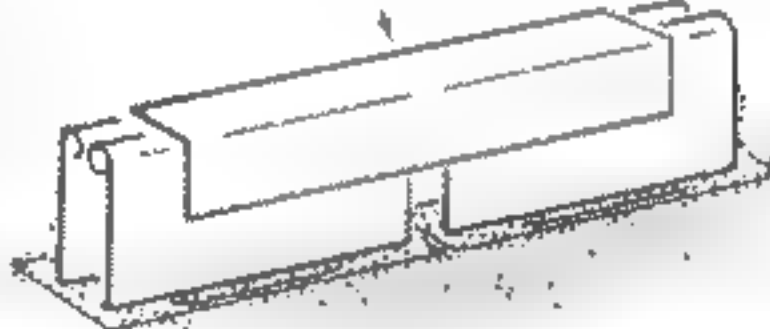
NOTE: Use the following procedure when you install the four input contacts that make up the two input test jacks in the next five steps.

Refer to Detail 2-1A and install two input contacts at the location shown. Squeeze both contacts together and hold them down against the circuit board while you temporarily solder both tabs of each contact on the foil side of the circuit board.

In the same manner, install and solder the remaining two input contacts at the other input jack location.

Place the insertion tool over the four input contacts as shown below. Reheat and solder both tabs of each of the four contacts to the foil side of the circuit board.

INSERTION TOOL

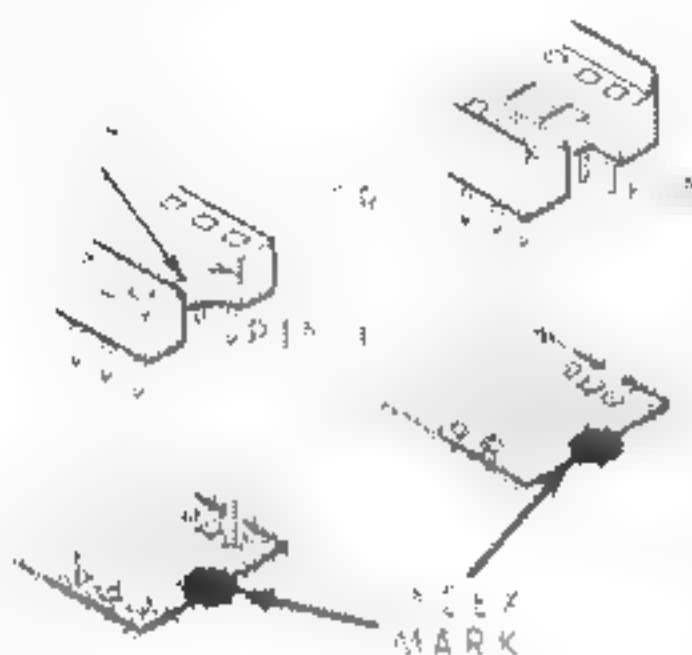


Refer to Detail 2-1B and solder the outside edge of each of the four input contacts to the circuit board as shown.

NOTE: Leave the insertion tool in place until you are directed to remove it later.

START

NOTE: To install an IC socket, insert the socket pins into the holes. The index mark on the circuit board must stay visible after the socket is installed. Solder the pins to the foil as you install each socket and cut off any excess pin lengths.



Install two 8-pin IC sockets at

(✓) U101

(✓) U102

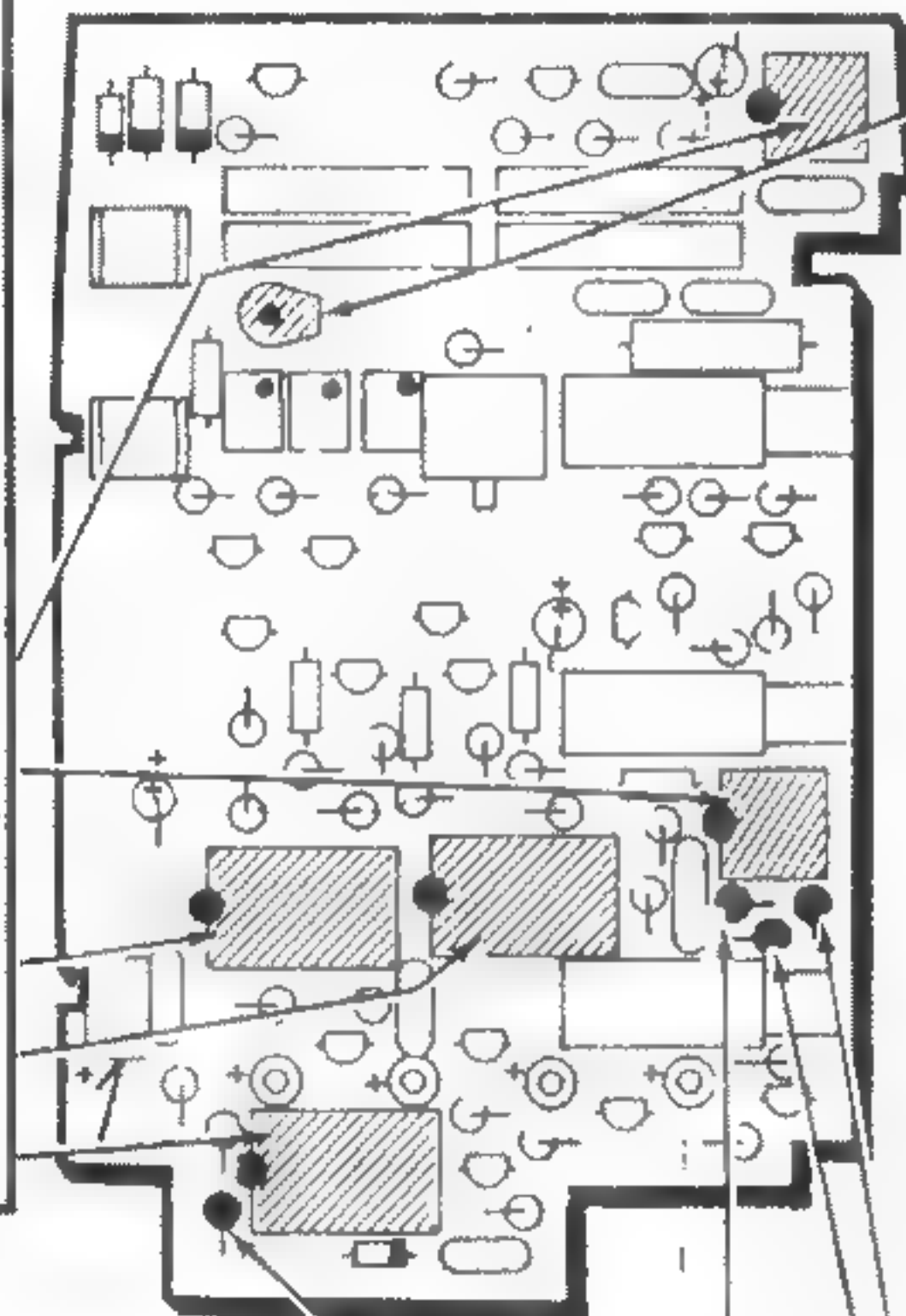
Install three 14-pin IC sockets at

(✓) U104

(✓) U103

(✓) U105

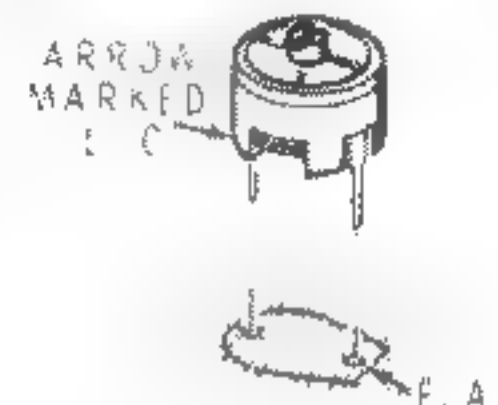
IMPORTANT: THE Banded end of diodes can be marked in a number of ways



PICTORIAL 2-2

CONTINUE

104 15-60 pF ceramic capacitor
at locations #11-65. Solder the capacitor to the board markings at this location. Position the lug marked with a band away from the outside of the flat on the circuit board. Then insert the legs into the corresponding holes of the circuit board and solder them in place. NOTE: You will need to bend the lugs slightly to fit the circuit board holes.



NOTE: Use the following procedure when a step directs you to install a diode

1. Hold the diode lead with pliers so you do not break the diode body
2. Bend the indicated lead before you install the diode
3. Position the diode with the banded end down over the circle outline on the circuit board



(✓) D106 1N4149 diode #56-56

(✓) D105 1N4149 diode #56-56

(✓) D104 1N4149 diode #56-56

(✓) D107 1N4149 diode #56-56

Solder the leads to the foil and cut off the excess lead lengths

START

NOTE: Mount the following resistors vertically to the circuit board as shown. Be sure each resistor is still vertical to the circuit board after you solder the leads to the foil.



(✓) R144: 1000 Ω (brn-blk-red)

(✓) R115: 10 Ω , 1% (brn-blk-blk-gold)

(✓) R122: 1500 Ω , 1% (brn-grn-blk-brn)

(✓) R128: 1.74 M Ω , 1% (brn-viol-yel-yel)

() R120: 4700 Ω (yel-viol-red)

() R126: 4700 Ω (yel-viol-red)

(✓) R124: 47 k Ω (yel-viol-org)

(✓) R127: 47 k Ω (yel-viol-org)

(✓) Solder the leads to the foil and cut off the excess lead lengths.

(✓) R121: 47 k Ω (yel-viol-org)

(✓) R134: 10 k Ω (brn-blk-org)

(✓) R131: 10 k Ω (brn-blk-org)

() R132: 10 k Ω (brn-blk-org)

() R140: 4700 Ω (yel-viol-red)

() R139: 4700 Ω (yel-viol-red)

(✓) R138: 4700 Ω (yel-viol-red)

(✓) R136: 10 k Ω (brn-blk-org)

() Solder the leads to the foil and cut off the excess lead lengths

CONTINUE

(✓) R142: 1000 Ω (brn-blk-red)

(✓) R143: 10 k Ω (brn-blk-org)

(✓) R141: 10 k Ω (brn-blk-org)

() R101: 100 k Ω (brn-blk-yel)

(✓) R116: 30.1 Ω , 1% (org-blk-brn-gold)

(✓) R106: 5000 Ω , 1% (grn-blk-blk-brn)

(✓) R105: 5000 Ω , 1% (grn-blk-blk-brn)

(✓) Solder the leads to the foil and cut off the excess lead lengths

() R104: 5000 Ω , 1% (grn-blk-blk-brn)

(✓) R109: 4700 Ω (yel-viol-red)

(✓) R107: 47 k Ω (yel-viol-org)

(✓) R108: 1000 Ω (brn-blk-red)

(✓) R110: 47 k Ω (yel-viol-org)

(✓) R113: 4700 Ω (yel-viol-red)

(✓) R111: 47 k Ω (yel-viol-org)

(✓) Solder the leads to the foil and cut off the excess lead lengths

(✓) R133: 1000 Ω (brn-blk-red)

() R135: 10 k Ω (brn-blk-org)

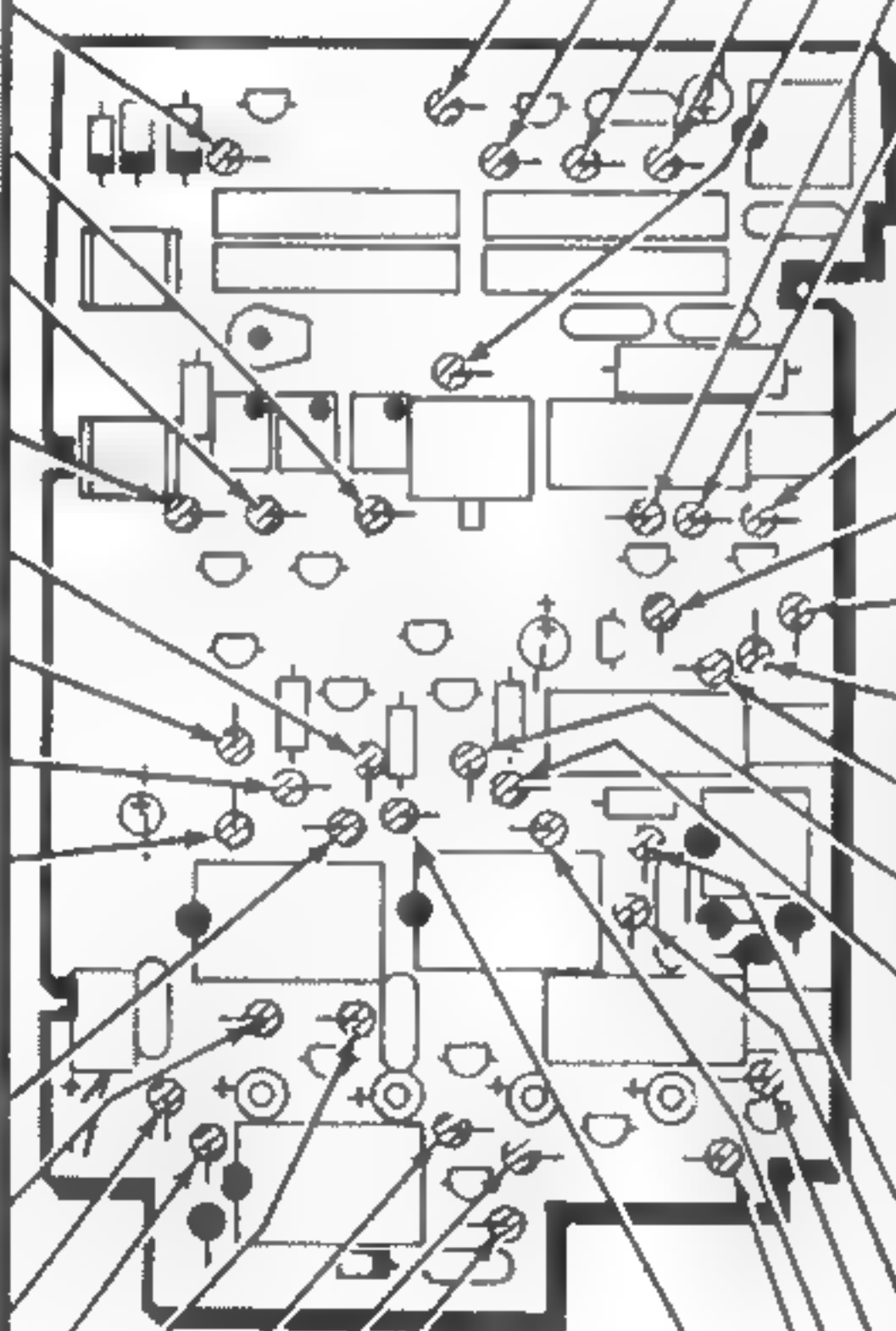
(✓) R137: 4700 Ω (yel-viol-red)

(✓) R114: 47 k Ω (yel-viol-org)

() R145: 680 Ω (blu-gry-brn)

(✓) R118: 47 k Ω (yel-viol-org)

(✓) Solder the leads to the foil and cut off the excess lead lengths



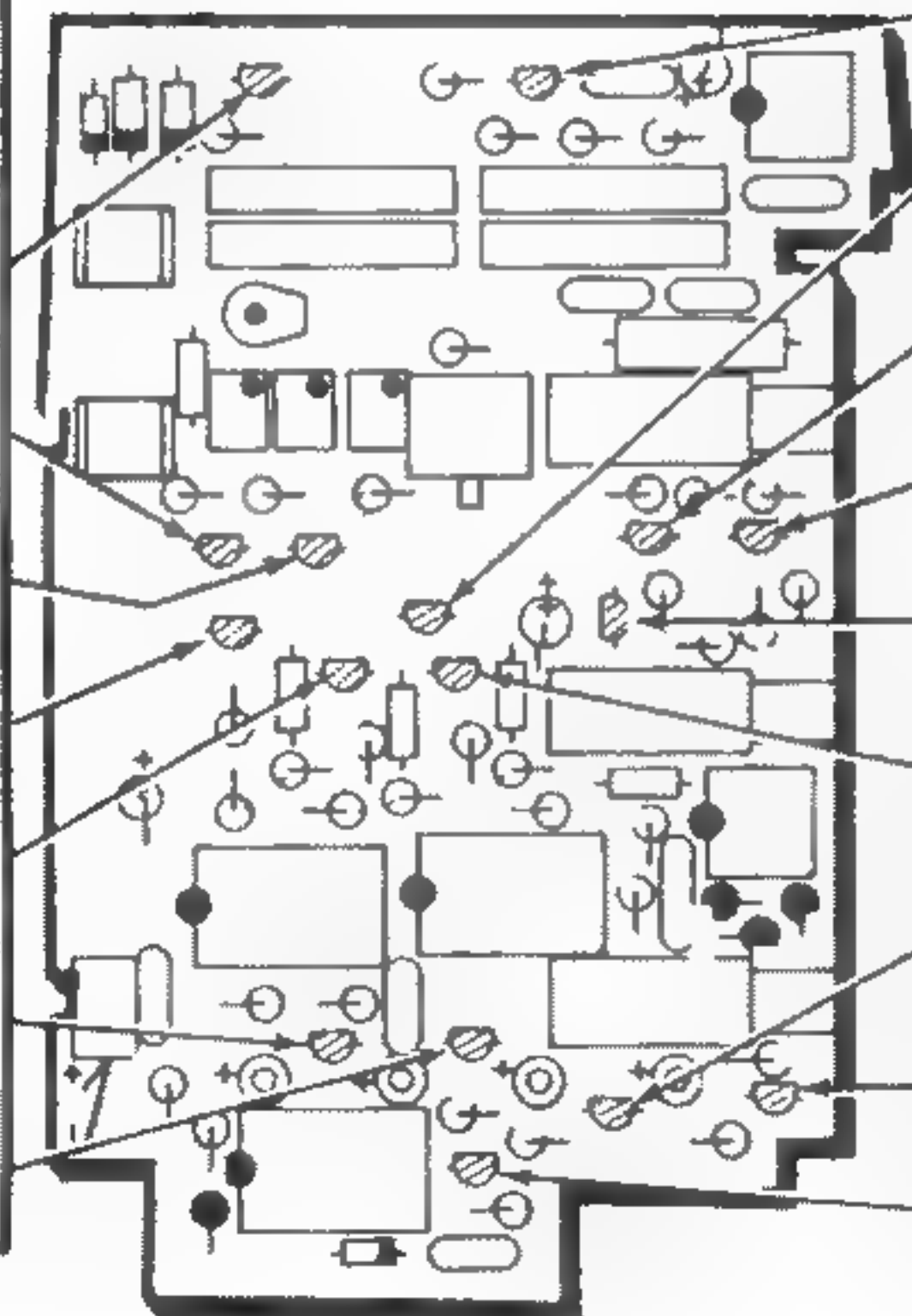
PICTORIAL 2-3

START

NOTE: Install the following transistors in the manner shown. First line up the flat on the transistor with the outline of the flat on the circuit board. Insert the transistor leads into the corresponding holes. Position the transistor $1/8"$ above the circuit board before you solder each lead to the foil. Cut off the excess lead lengths.



- () Q110 MPSA55 transistor (#417-865)
- () Q107 MPSA55 transistor (#417-865).
- () Q105 MPSA55 transistor (#417-865)
- () Q108 MPSA05 transistor (#417-864).
- () Q106 MPSA05 transistor (#417-864).
- () Q114 MPSA05 transistor (#417-864)
- () Q113 MPSA05 transistor (#417-864).

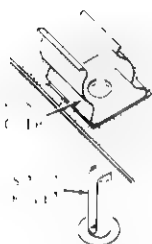
**CONTINUE**

- () Q109 MPSA05 transistor (#417-864)
- () Q103 MPSA55 transistor (#417-865).
- () Q102 MPSA05 transistor (#417-864)
- () Q101 MPSA55 transistor (#417-865)
- () Q116 MPSA05 transistor (#417-864)
- () Q104 MPSA05 transistor (#417-864)
- () Q112 MPSA05 transistor (#417-864)
- () Q111 MPSA05 transistor (#417-864)
- () Q115 MPSA05 transistor (#417-864)

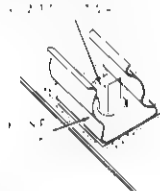
PICTORIAL 2-4

START

1. Install a fuse chip with a split rivet at the indicated location.



2. Place the circuit board foil-side-down on a hard surface. Use a screwdriver to spread the tabs of the rivet apart and press them flat against the inside of the fuse chip as shown.



3. Similarly, install a fuse chip with a split rivet at the indicated location.

4. Install the fuses on the fuse chips to align them.

5. Slide the fuses in the chips until it is only part way in one of the chips. Then solder the tabs of the exposed rivet to the inside of its fuse chip.

6. Now slide the fuses the other way in the chips to expose the other rivet. Then solder the tabs of this rivet to its fuse chip.

7. Solder the two foil circuit board leads to the circuit board.

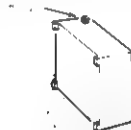
8. Remove the fuses.

CONTINUE

1. R102: 22 Ω , 2-watt (red red-gold). Solder the leads to the foil and cut off the excess lead lengths.

Install the next three controls as follows:

1. Position the control with the small adjustment screw as shown.
2. Insert the leads into the circuit board, solder them to the foil, and cut off the excess lead lengths. Note the position of the screw.



NOTE: Controls R117 and R118, installed in the next two steps, may fit very tight. If necessary, wiggle the controls slightly as you insert them. Do not bend the leads.

3. R117: 100 Ω (W100) control (#10-1167)

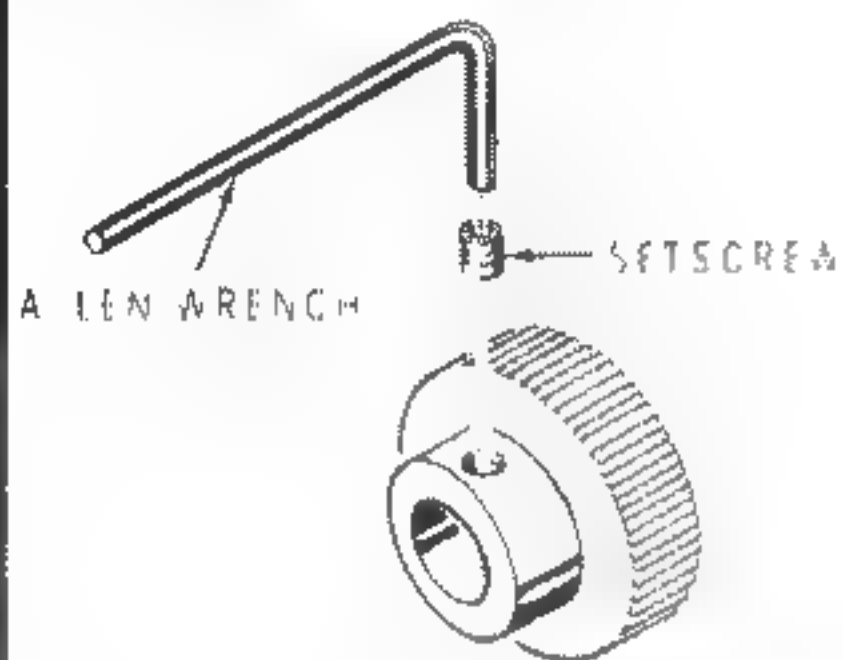
4. R124: 1000 Ω (W1k) control (#10-1168)

5. R129: 500 k Ω (W500k) control (#10-1166)

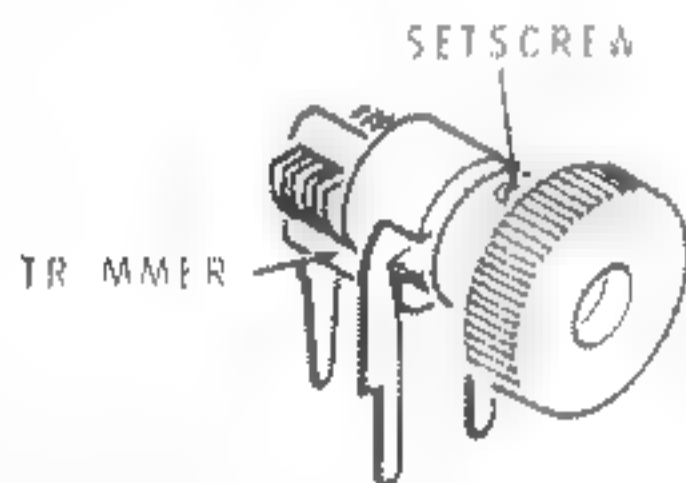
PICTORIAL 2-5

START

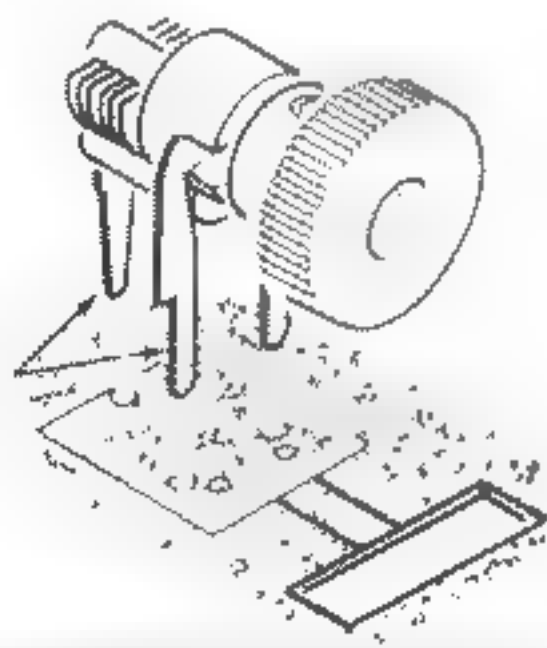
Start a 4-40 x 1/2" setscrew in the round knob. Use the allen wrench supplied with this kit.



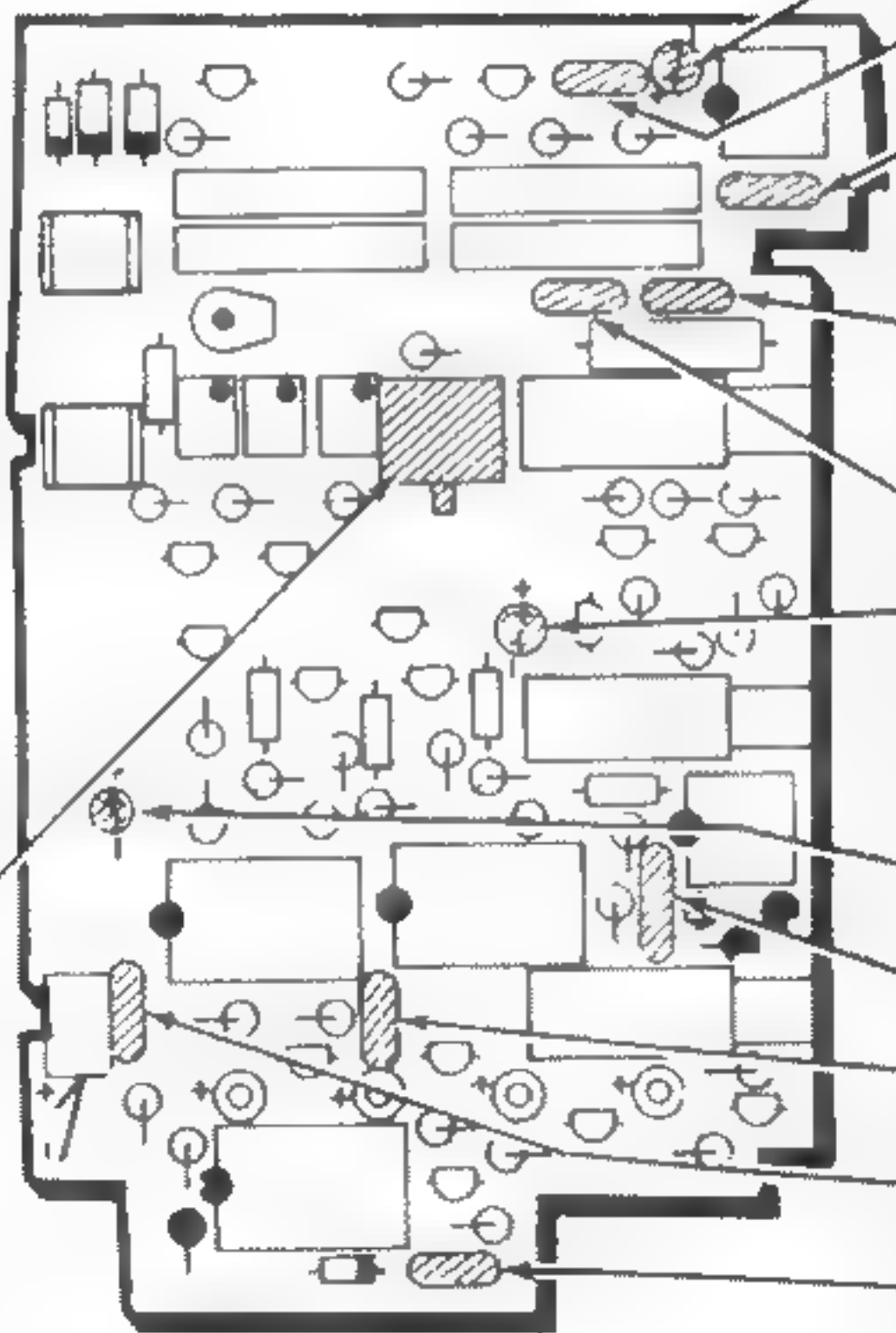
Place the round knob on the shaft of the air trimmer capacitor as shown.



Q103 13-54 pF air trimmer capacitor (#26-166). Insert the lugs into the corresponding holes in the circuit board and solder them to the foil. Cut off the excess lug lengths.



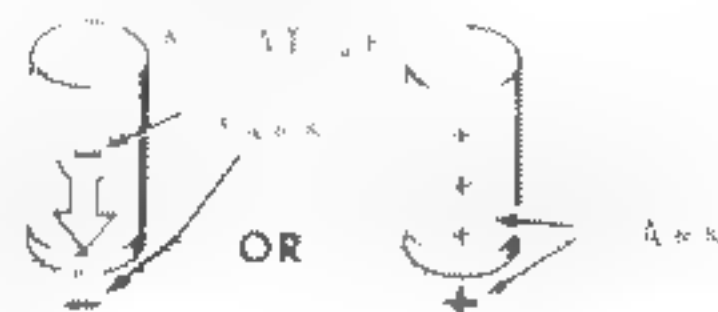
Enter the knob in the slot in the circuit board. Then tighten the setscrew, but do not overtighten.



PICTORIAL 2-6

CONTINUE

When you install an electrolytic capacitor, always match the positive (+) mark on the capacitor with the positive (+) mark on the circuit board. OR match the negative (-) mark on the capacitor with the negative (-) mark on the circuit board.



Q101 10 μ F electrolytic

Q102 5 pF mica

Q102A 470 pF mica. Red wax seal.

Insulation before you install this capacitor so that its maximum height does not exceed 5/16".

Q103 13-54 pF

Q104 10 μ F electrolytic

Solder the leads to the foil and cut off the excess lead lengths.

Q105 10 μ F electrolytic

Q106 1 μ F 104M ceramic

Q107 7 pF mica

Q108 10 μ F ceramic

Q109 30 pF mica

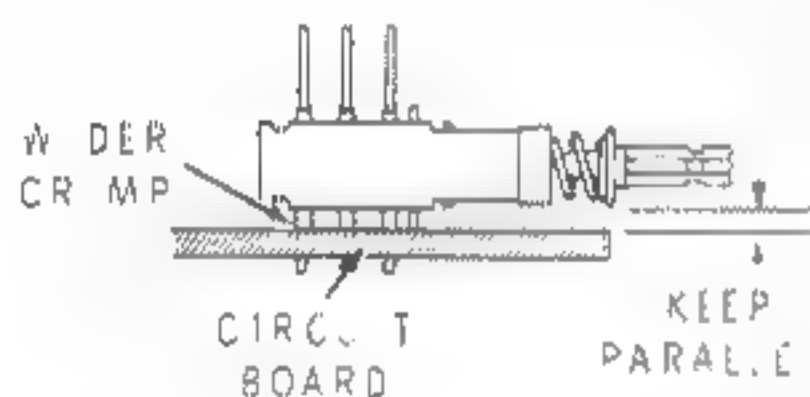
Solder the leads to the foil and cut off the excess lead lengths.

START

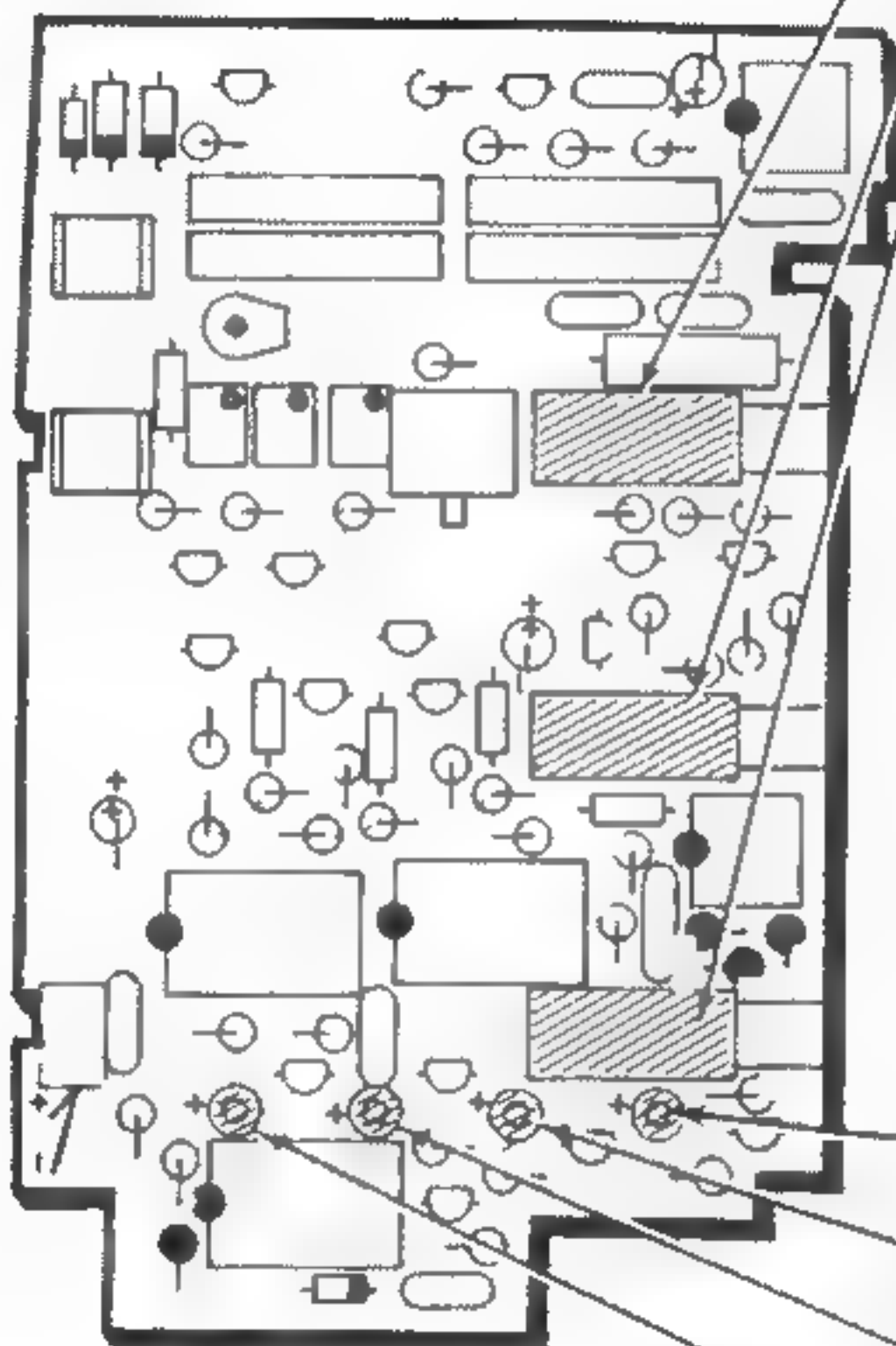
- () Locate the three switches. Depress the shaft of each switch to determine which one has the locking action. Use that switch in the next step.

NOTE: Use the following procedure when you install each of the switches.

- 1 Insert the pins with the wider crimped portion into the circuit board holes.
- 2 Make sure the crimped portion of each pin is fully seated against the circuit board.



- 3 Turn the circuit board over and solder the four corner pins of the switch to the foil. Check the switch and make sure it is parallel to the circuit board. Then solder the other switch pins to the foil.
- 4 Cut off the excess pin lengths that protrude thru the circuit board.

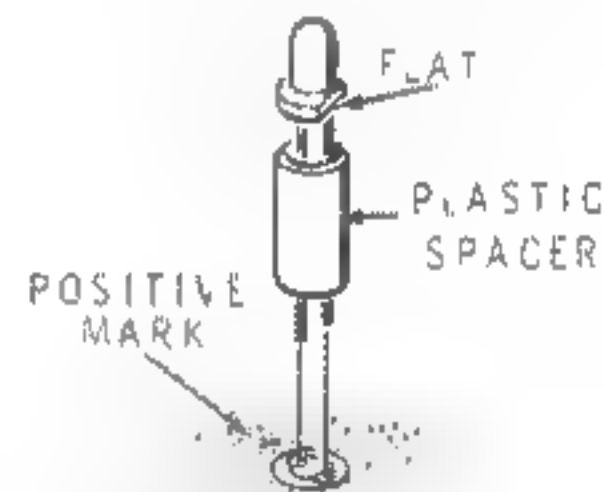


PICTORIAL 2-7

CONTINUE

- () SW101: Switch w locking action
- () SW103: Switch w momentary action
- () SW102: Switch w momentary action

NOTE: When you install an LED lamp place a plastic spacer over both leads as shown. Match the lead **opposite the flat** with the positive (+) marked hole on the circuit board. Insert the leads into the holes and solder them to the foil. Cut off the excess lead lengths.



- () D109: LED lamp (#412-79)
- () D110: LED lamp (#412-79)
- () D111: LED lamp (#412-79)
- () D112: LED lamp (#412-79)

FINISH

CIRCUIT BOARD CHECKOUT

Carefully inspect the circuit board for the following most commonly made errors

- (X) Unsoldered connections
- (X) Poor solder connections
- (X) Solder bridges between foil patterns
- (X) Protruding leads which could touch together

Refer to the illustration where the parts were installed as you make the following visual checks

- () Diodes for the proper type and installation
- () Transistors for the proper type and installation
- (X) LED lamps for the correct position of the "flat side."
- (X) Electrolytic capacitors for the correct position of the (+) or (-) marked lead.

NOTE: Be sure all leads are trimmed as close as possible to the circuit boards, especially protruding leads from I.C. Sockets.

Refer to Pictorial 2-8 to install the ICs in the following steps. Be sure to install each IC correctly. Refer to the information on Page 16 if necessary.

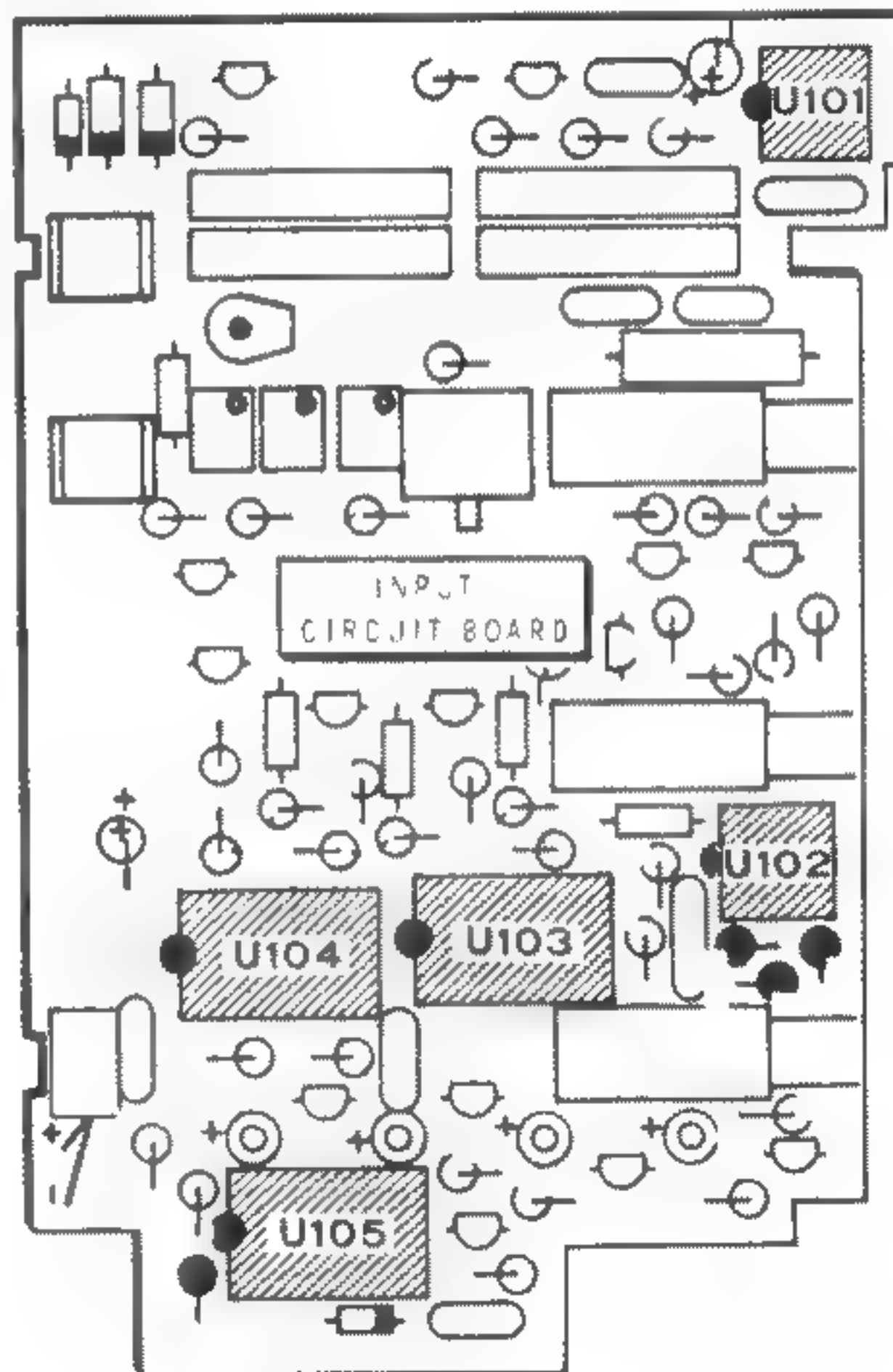
(X) U101 CA3130E IC (#442-715) at U101

(X) U102 5741 IC (#442-22) at U102

(X) U103 4011 IC (#443-603) at U103

(X) U104 4081 IC (#443-751) at U104

(X) U105 4011 IC (#443-603) at U105



PICTORIAL 2-8

Heathkit

Refer to Pictorial 2-9, Illustration B (Inset, Page 3) for the following steps:

NOTE: When you are instructed to prepare a wire as in the following step, cut it to the indicated length and remove 1/8" of insulation from each end. Then twist the small wire strands together and melt a small amount of solder on the bare wire ends to hold the strands together.

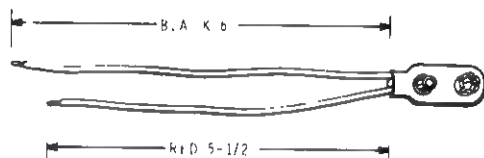
- ✓ Prepare the following wires:

4-1 2' black
3" green

NOTES

1. In the following steps "S-" with a number, such as (S-1), means to solder the connection. The number following the "S" tells how many wires are at the connection.
 2. Whenever you are instructed to connect a wire to a switch pin, make sure you connect the wire to the lower portion of the pin. Refer to the inset drawing on Pictorial 2-9.
- ✓
1. Position the circuit board as shown in the Pictorial.
 1. Connect one end of the 4-1 2' black wire to switch SW101 pin 3 (S-1). Route the free end of this wire as shown in the Pictorial and connect it to circuit board hole B (S-1).

1. Connect one end of the 3" green wire to switch SW102 pin 5 (S-1). Route the free end of this wire as shown in the Pictorial and connect it to circuit board hole B (S-1).



Detail 2-9A

1. Refer to Detail 2-9A and cut the black battery connector wire to 6" and the red wire to 7-1/2". Then tie a knot in the wires 3" away from the battery connector as shown in the Pictorial.

Connect the battery connector wires to the circuit board as follows:

1. Red wire to hole A (S-1)
1. Black wire to hole D (S-1)

Refer to Pictorial 2-10 for the following steps.

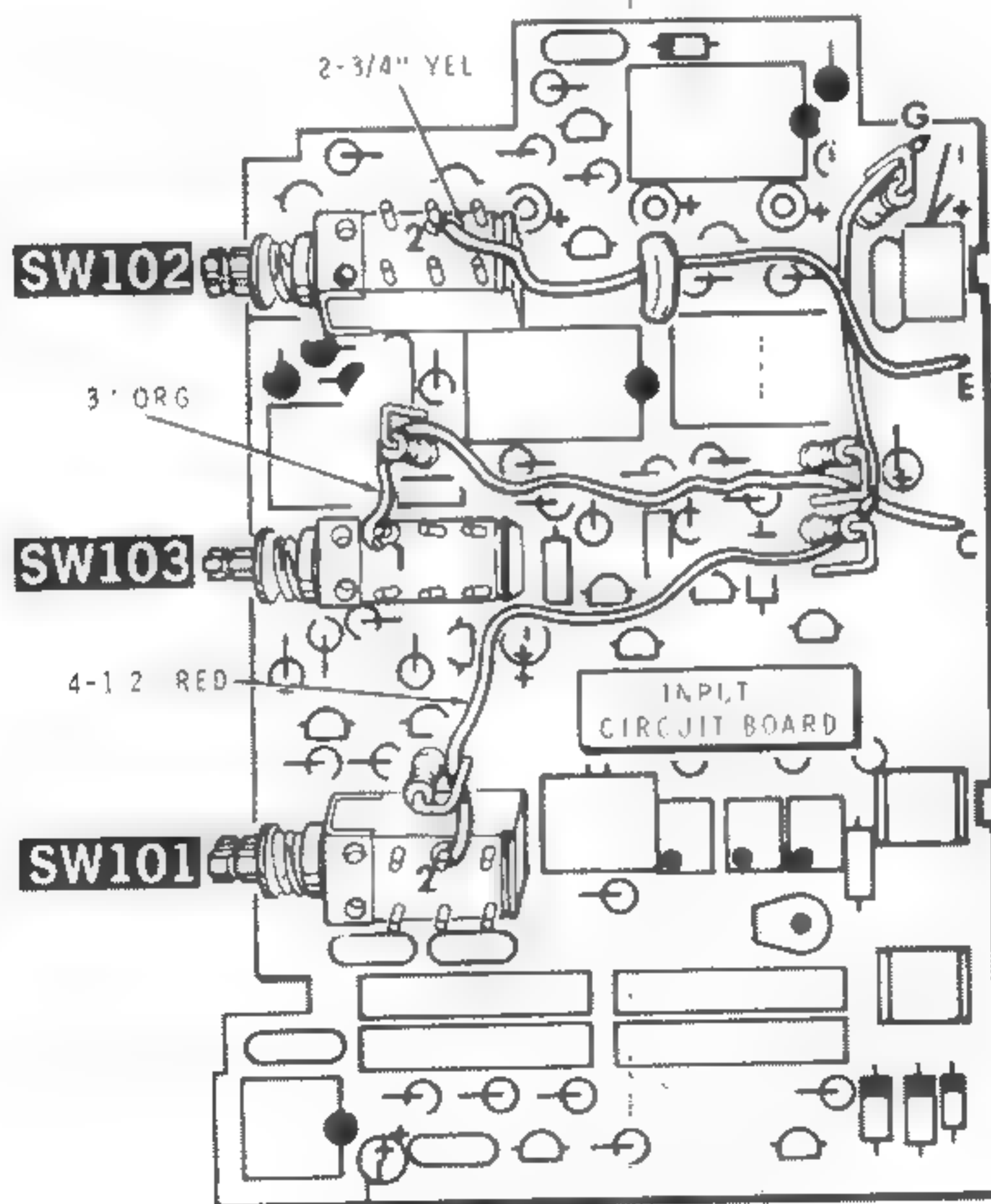
(1) Prepare the following wires

4-1/2' red
3' orange
2-3/4' yellow

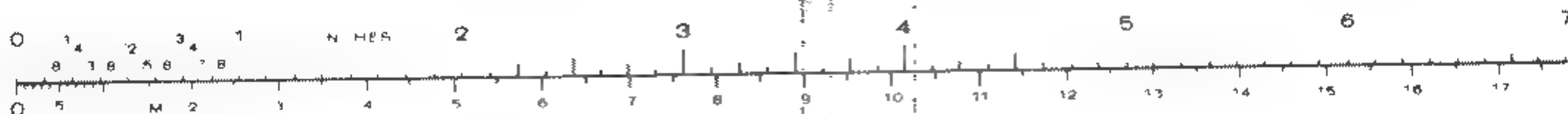
(2) Connect one end of the 4-1/2' red wire to switch SW101 pin 2 (S-1). Position this wire down as close as possible to the switch surface. Route the free end of this wire as shown in the Pictorial and connect it to circuit board hole G (S-1).

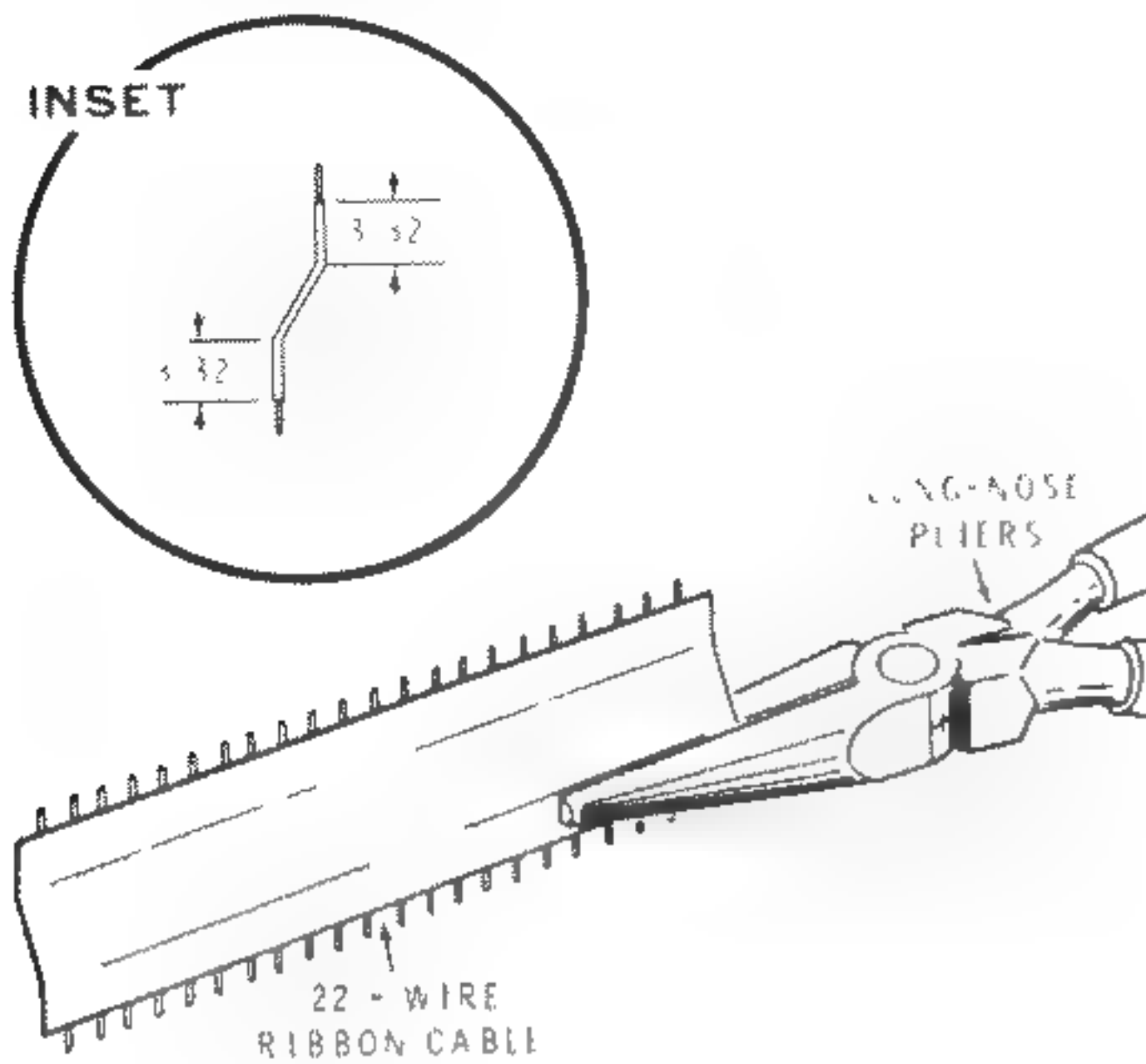
(3) Connect one end of the 3' orange wire to switch SW103 pin 1 (S-1). Position this wire down as close as possible to the switch surface. Route the free end of this wire as shown in the Pictorial and connect it to circuit board hole C (S-1).

(4) Connect one end of the 2-3/4' yellow wire to switch SW102 pin 2 (S-1). Position this wire down as close as possible to the switch surface. Route the free end of this wire as shown in the Pictorial and connect it to circuit board hole E (S-1).



PICTORIAL 2-10





Detail 2-11A

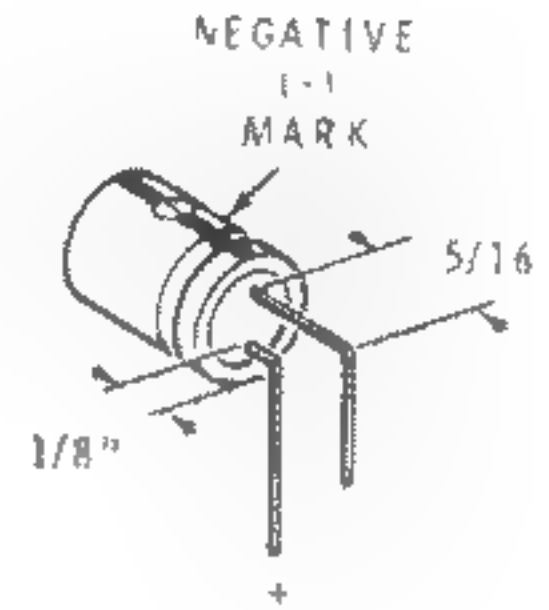
Refer to Pictorial 2-11 (Illustration Booklet, Page 3) for the following steps

- (✓) Locate the 22-wire ribbon cable

CAUTION: Do **NOT** allow the ends of the ribbon cable to be flexed more than necessary before or after you install it. Excessive flexing may break one or more pins.

- (✓) Refer to Detail 2-11A and its inset drawing and preform the 22-wire ribbon cable as shown. Use long-nose pliers.

- (✓) Position the 22-wire ribbon cable as shown in the Pictorial. Then match the pins of the ribbon cable with the corresponding row of holes from the **bottom** side of the input circuit board. Be sure the cable is fully seated against the circuit board and all the pins protrude through the circuit board. Then solder all the pins to the **top** side of the circuit board and cut off the excess pin lengths. **CAUTION:** Be careful that you do not burn the insulation on any circuit board wire with the soldering iron.



Detail 2-11B

- (✓) Refer to Detail 2-11B and bend the leads of the 100 μ F electrolytic capacitor as shown. Use long-nose pliers. **NOTE:** Make sure you position the capacitor with the polarity markings (+ or -) as shown before you bend the leads.

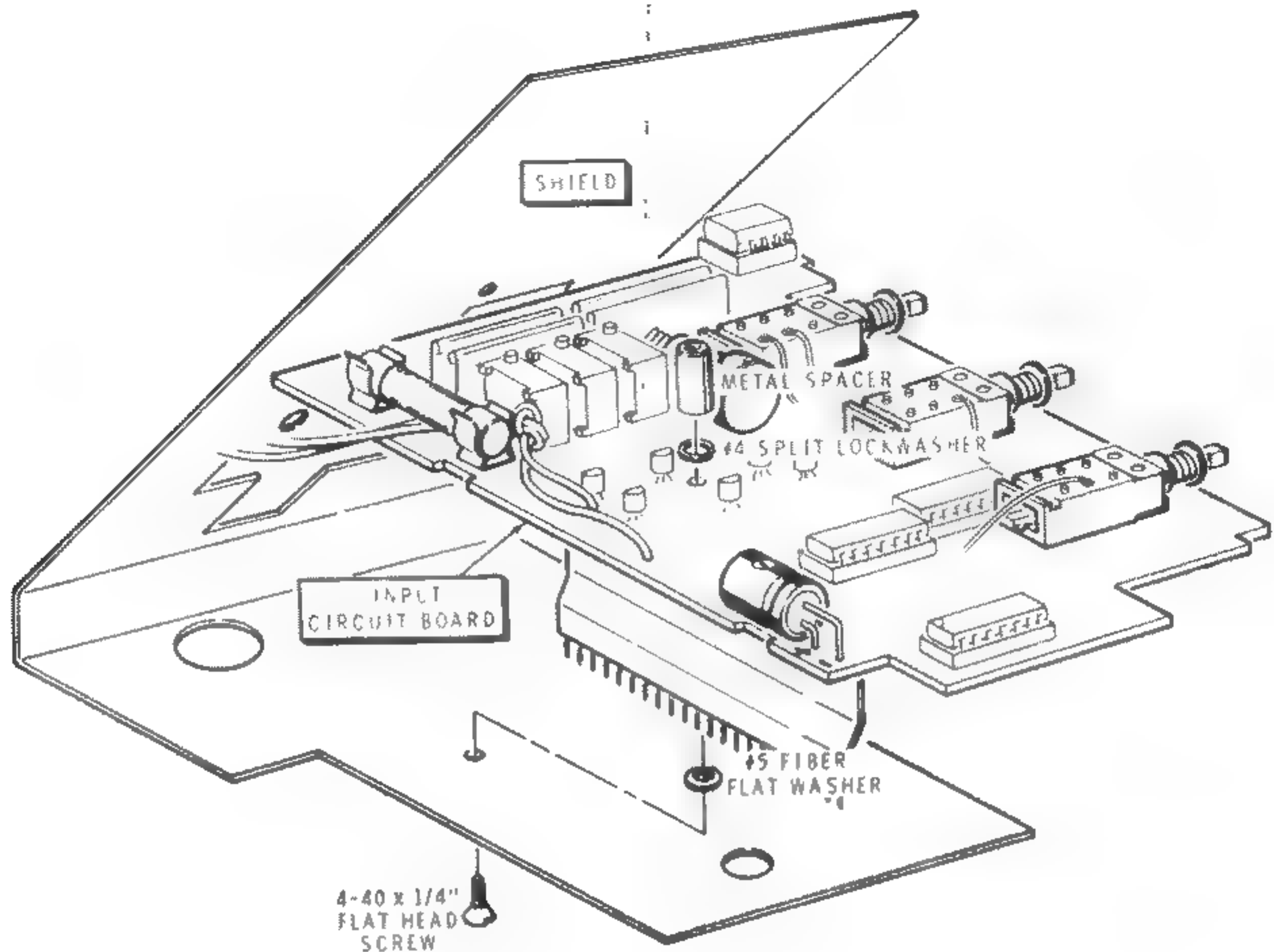
- (✓) C113: Install the 100 μ F electrolytic capacitor as shown in the Pictorial. Solder the leads to the foil and cut off the excess lead lengths.

- (✓) Refer to the inset drawing on Pictorial 2-11 and cut off each of the switch pins on the three switches to a maximum height of 1/16". Be sure the tops of the cut off pins do not come to a sharp point. Failure to do this may cause a short during Final Assembly.

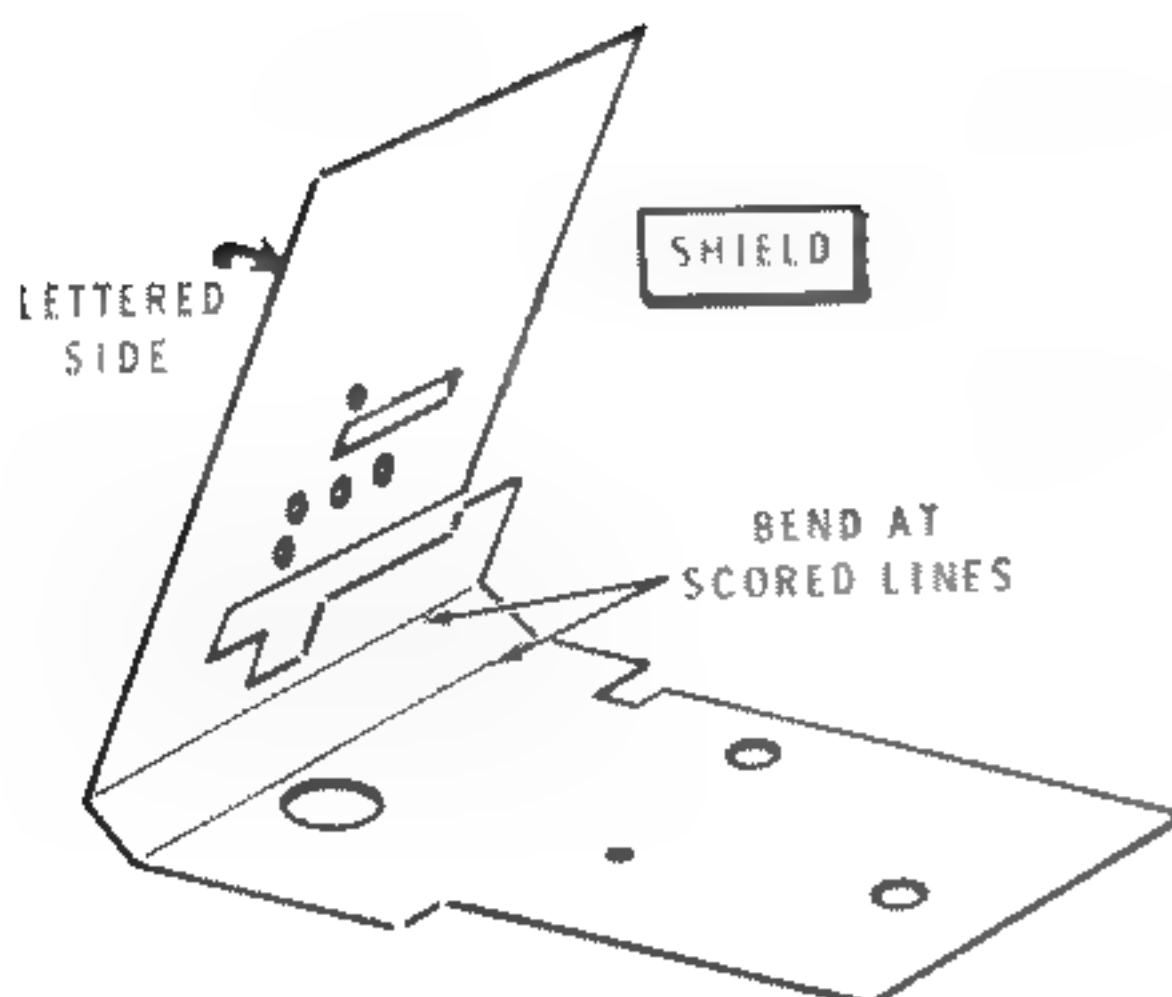
- (✓) F101: Install the 1/4-ampere fuse in the fuseholder on the input circuit board. Be sure the battery connector wires are routed under the fuse as shown.

- (✓) Be sure all excess wire and lead lengths are cut as short as possible on the foil side of the input circuit board.

- (✓) Carefully remove the insertion tool from the four input contacts.



PICTORIAL 2-12



Detail 2-12A

Refer to Pictorial 2-12 for the following steps

- (1) Refer to Detail 2-12A and form the shield as shown by bending it at the two scored lines
- (2) Mount the shield to the input circuit board as shown in the Pictorial. Use a metal spacer, a #4 split lockwasher, a #5 fiber flat washer, and a 4-40 x 1/4" flat head screw

This completes the "Step-by-Step Assembly" of the input circuit board. Set this circuit board assembly aside until it is called for in a step

DISPLAY CIRCUIT BOARD

PARTS LIST

Remove the parts from Pack 3 and check each part against the following list. The key numbers correspond to the numbers on the "Display Circuit Board Parts Pictorial" (Illustration Booklet, Page 4).

To order a replacement part, always include the **PART NUMBER**. Use the Parts Order Form furnished with this kit. If a Parts Order Form is not available, refer to "Replacement Parts" inside the rear cover of this Manual. For prices, refer to the separate "Heath Parts Price List."

KEY No	HEATH Part No	QTY	DESCRIPTION	CIRCUIT Comp No
A1	25-931	1	10 μ F electrolytic capacitor	C301
	85-2468-1	1	Display circuit board	
A2	92-699	2	Display bracket	
	100-1754	1	LCD socket assembly consisting of	
A3		1	LCD holder	
A4		2	Elastomeric contact strip	
A5	134-1113	1	16-wire ribbon cable	
A6	210-117	1	Bezel	
A7	250-4	2	4-40 \times 3/8" screw	
A8	252-2	2	4-40 nut	
A9	254-9	2	#4 lockwasher	
A10	411-843	1	LCD (liquid crystal display)	LCD301
A11	434-299	4	16-pin IC socket	

KEY No	HEATH Part No	QTY	DESCRIPTION	CIRCUIT Comp No
--------	---------------	-----	-------------	-----------------

NOTE: Integrated circuits are marked for identification in one of the following four ways:

1. Part number
2. Type number (On integrated circuits, use **only** those numbers and letter in **BOLD** print. Disregard any other numbers or letters.)
3. Part number and type number
4. Part number with a type number other than the one shown

A12	443-737	1	4518 IC	U304
A12	443-931	3	4543 IC	U301, U302, U303
A13	446-706	1	Window	
A14	490-5	1	Nut starter	
A15	490-193	1	Alignment blade	

PARTS FROM THE FINAL PACK

	100-1779*	1	Calibration package consisting of the following selected capacitors
A16		1	15 μ F polycarbonate
A17		1	150 μ F electrolytic
A18		1	1000 μ F electrolytic

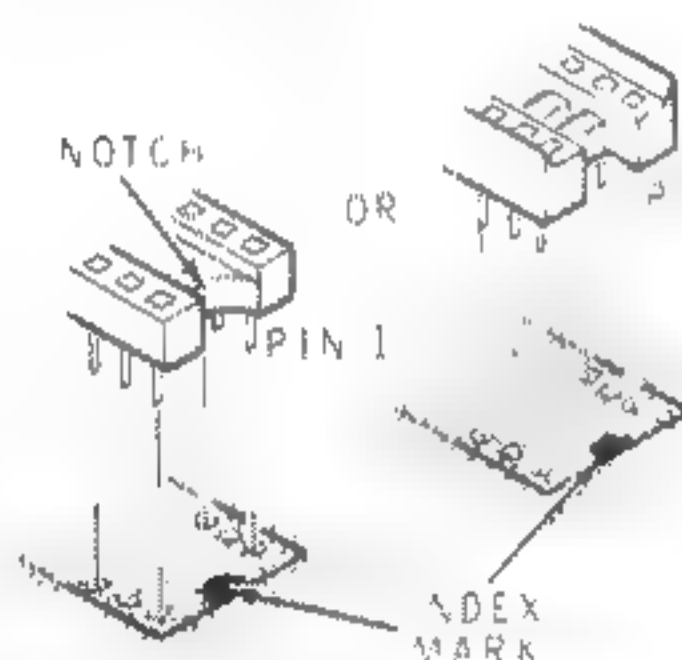
*Set this calibration package aside for use during the Calibration section of your Manual

STEP-BY-STEP ASSEMBLY

START →

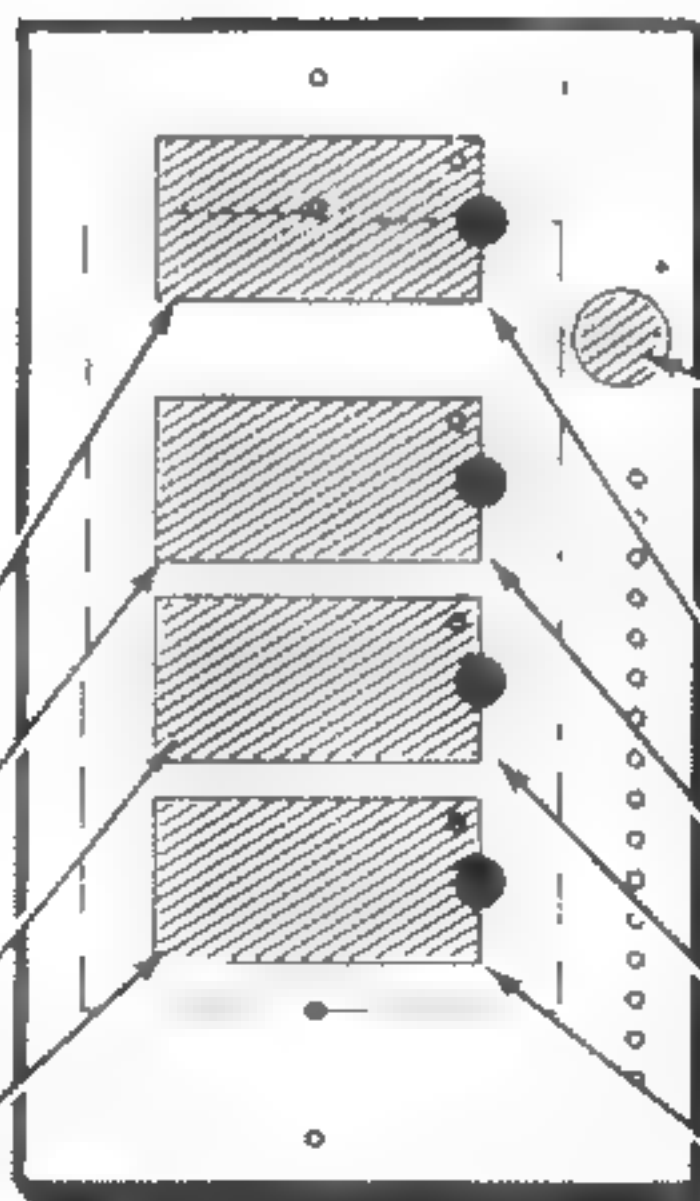
1) Position the display circuit board with the printed (lettered) side up as shown.

NOTE: To install an IC socket, insert the socket pins into the holes. The index mark on the circuit board must still be visible after the socket is installed. Solder the pins to the foil as you install each socket and cut off any excess pin lengths.



Install four 16 pin IC sockets at

- 1) U301
- 2) U302
- 3) U301
- 4) U304

**CONTINUE** →

C301 10 μ F electrolyt. Form the leads to fit the hole spacing. Solder the leads to the foil and cut off the excess lead lengths.

NOTE: Be sure to match the pin 1 end of each integrated circuit in the following steps, with the index mark on the circuit board.

1) U303 4543 IC (#443 931)

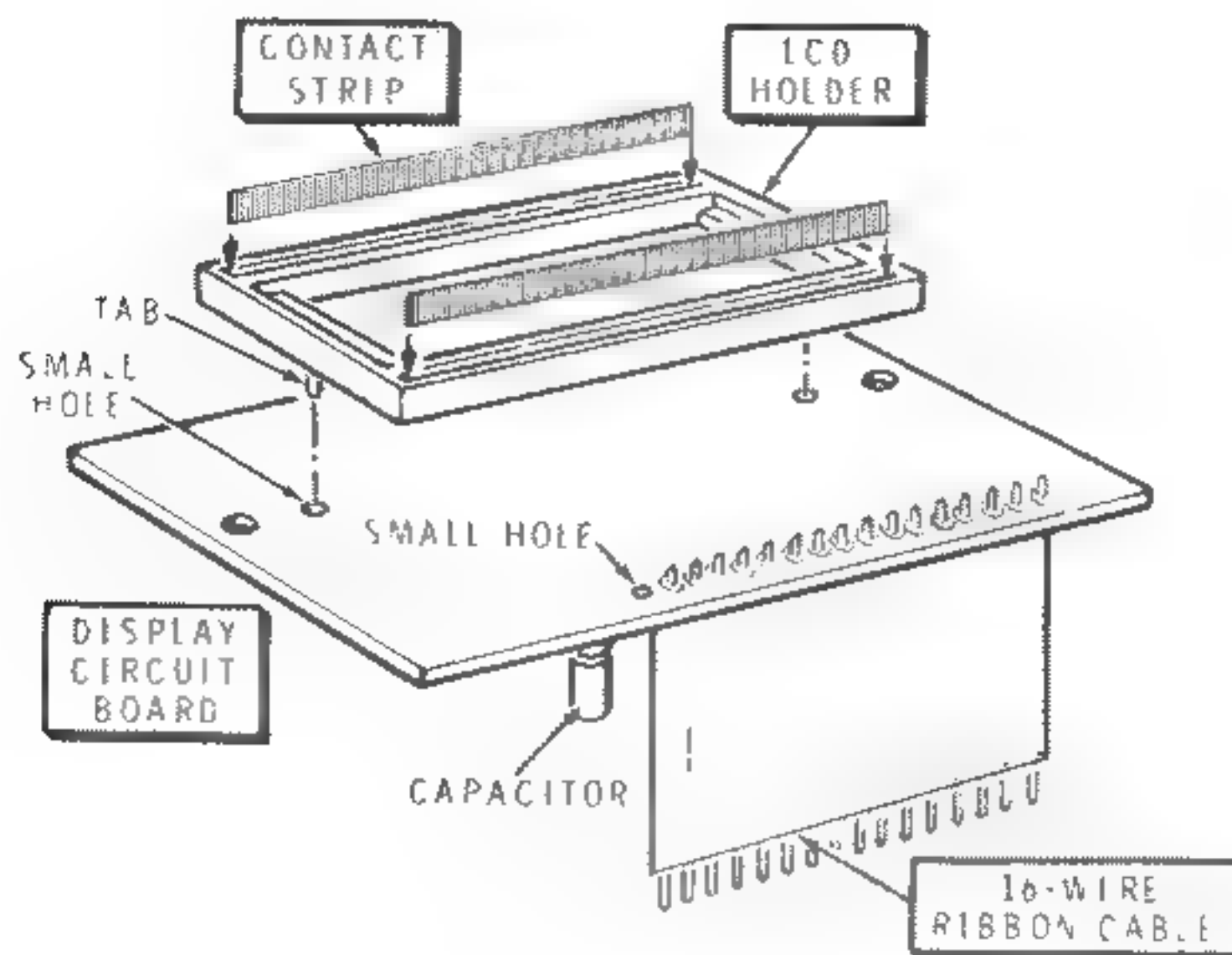
2) U302 4543 IC (#443 931)

3) U301 4543 IC (#443 931)

4) U304 4518 IC (#443 737)

FINISH

PICTORIAL 3-1



Detail 3-2A

Refer to Pictorial 3-2 (Illustration Booklet, Page 5) for the following steps.

- (1) Position the display circuit board as shown with the component side down. Note the location of the capacitor that was mounted earlier.

CAUTION: Do NOT allow the ends of the ribbon cable to be flexed more than necessary before or after you install it. Excessive flexing may break the pins.

- (2) Refer to Detail 3-2A and match the pins at either end of the 16-wire ribbon cable with the corresponding row of holes from the **bottom** lettered side of the display circuit board. Be sure the cable is fully seated against the circuit board and all the pins protrude through the circuit board. Be careful not to use the small hole indicated on the Pictorial. Then solder all the pins to the **top** side of the circuit board and cut off the excess pin lengths.

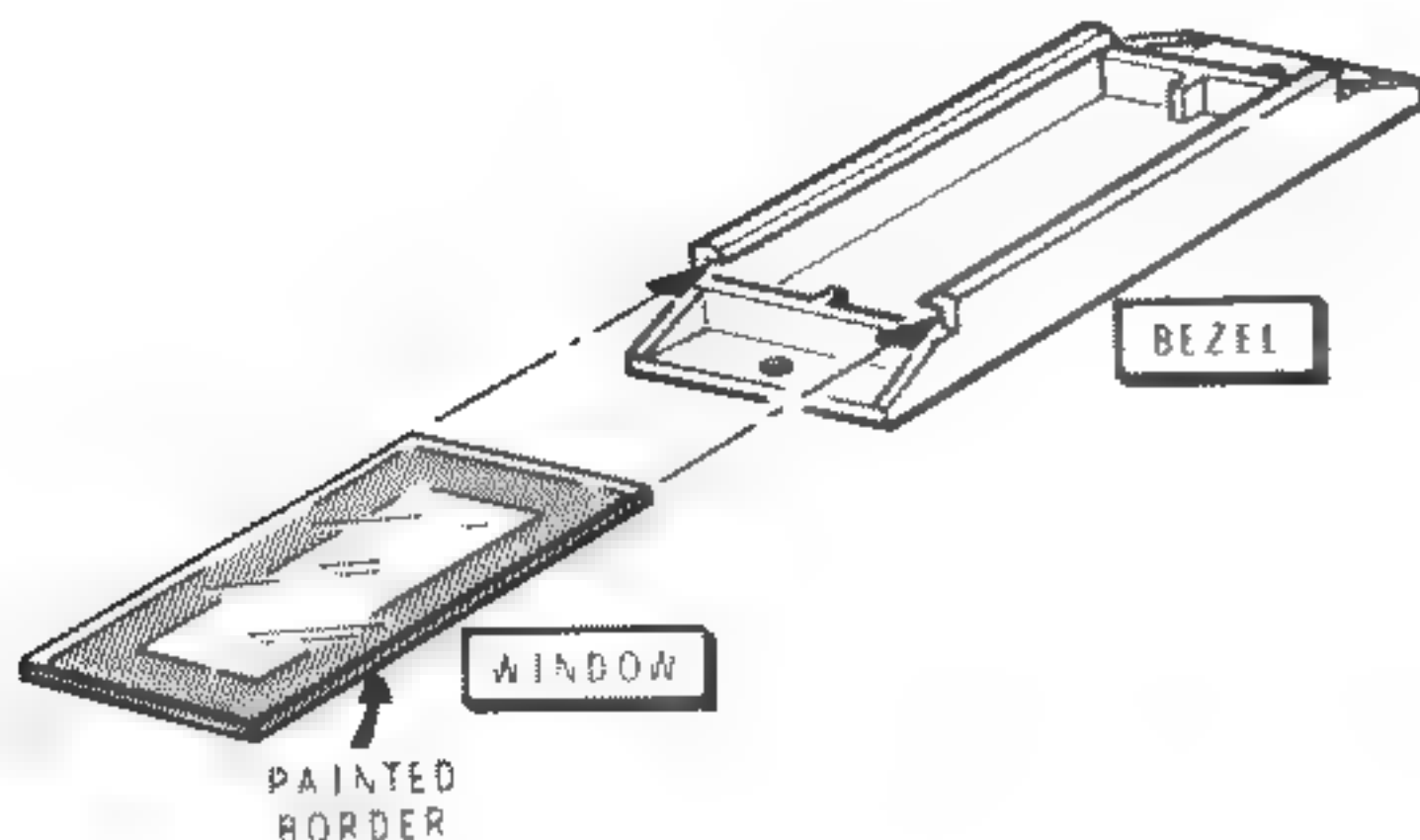
- (3) Refer again to Detail 3-2A and line up the tabs on the LCD holder with the corresponding small holes on the display circuit board. Then place the LCD holder on the circuit board.

NOTE: The contact strip may already have been installed in the LCD holder when you received the LCD socket assembly. If so, disregard the next two steps.

- (4) Carefully remove the two elastomeric contact strips from the envelope containing the LCD socket assembly. **CAUTION:** Be sure you do not stretch the contact strips.

- (5) Refer again to Detail 3-2A and insert a contact strip either way in each of the two slots in the LCD holder. Carefully push each contact strip so the entire length rests against the circuit board.

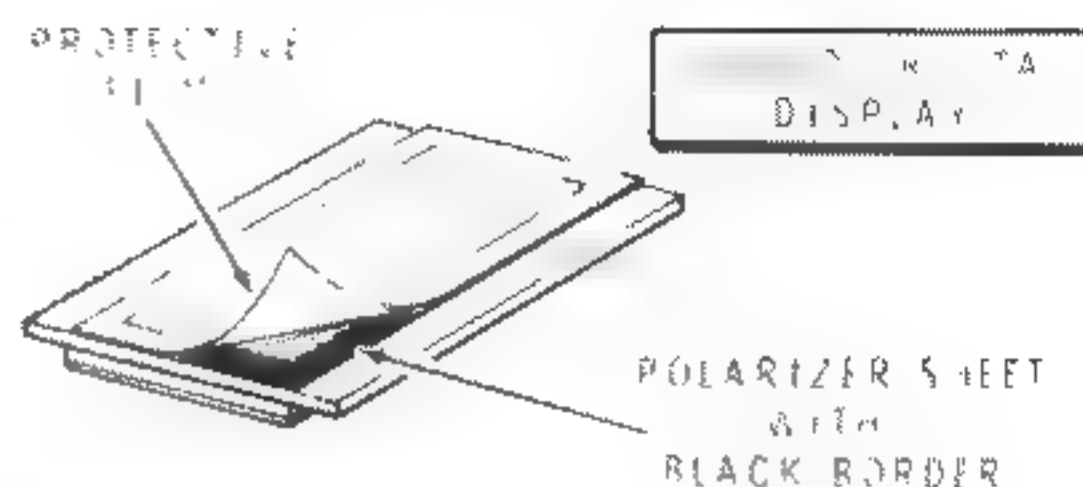
- (6) Make sure the window is free from fingerprints and dust.



Detail 3-2B

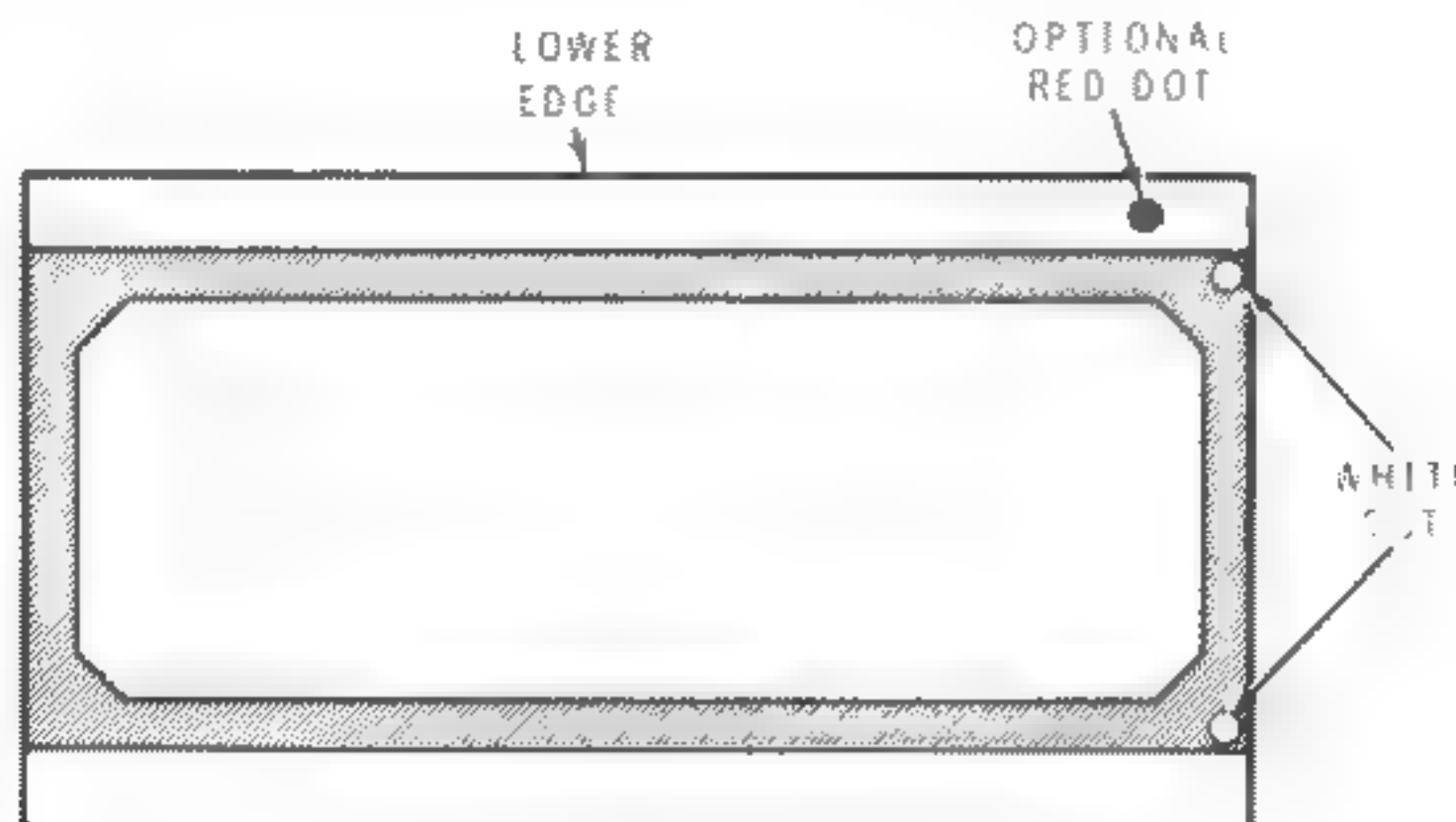
- (U) Refer to Detail 3-2B and place the window next to the bezel. Position the window so the side with the painted border faces down. Then slide the window into the grooves in the bezel. Center the window in the bezel.

CAUTION: The liquid crystal display (LCD) is supplied with a clear, protective film. In the following step, be sure you only remove this protective film. Do **NOT** remove the top surface, which is a plastic polarizer sheet. Also, be sure you do not scratch the polarizer sheet.



Detail 3-2C

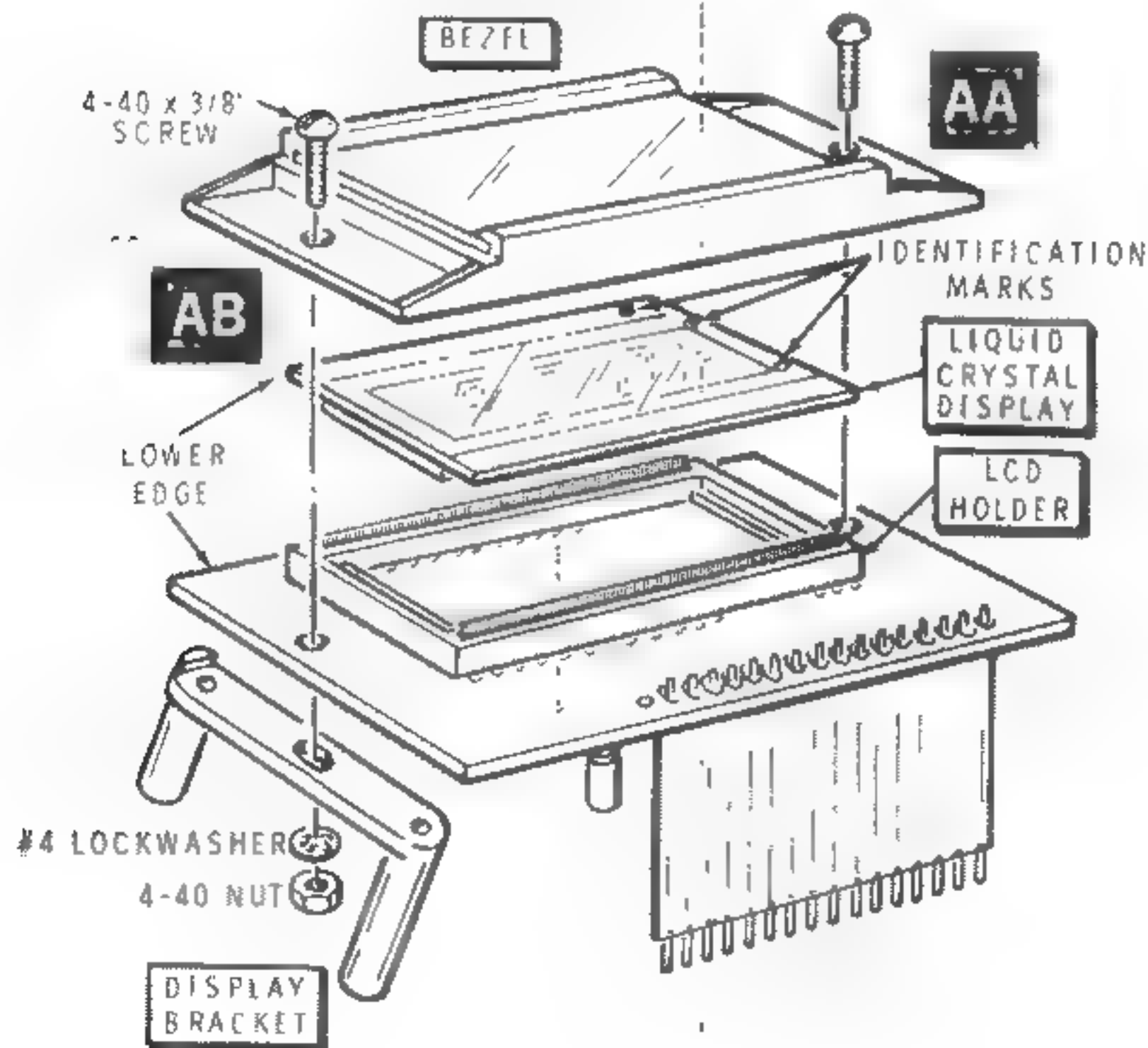
- () Refer to Detail 3-2C while you hold the liquid crystal display between your index finger and the thumb on one hand. Carefully lift just the corner of the clear, protective film from the top of the display with the other hand as shown in the Detail. Make sure the black border is still visible under the corner you just lifted. If so, completely remove the protective film. If not, push the polarizer sheet firmly down; then remove the protective film.
- () Refer to Detail 3-2D and locate the identification marks near one edge on the top surface of the liquid crystal display. This identifies the lower edge of the display.



Detail 3-2D

- (v.) LCD301: Refer to Detail 3-2E and place the display in the LCD holder so the lower edge of the display is near the lower edge of the circuit board

Mount the bezel to the display circuit board assembly as shown in Detail 3-2E. Use a display bracket, a 4-40 \times 3/8" screw, a #4 lockwasher and a 4-40 nut at AA and AB



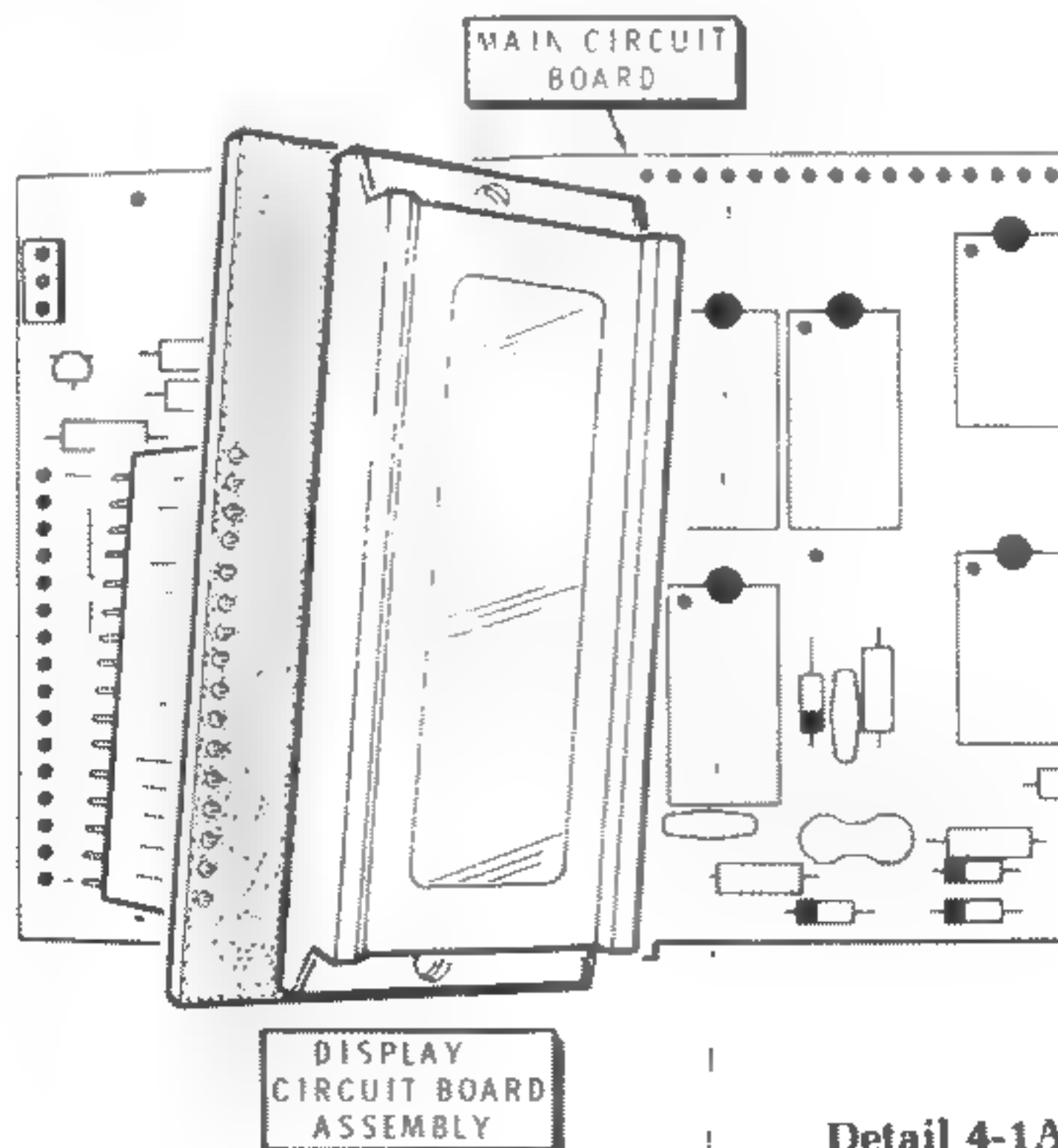
Detail 3-2E

GENERAL ASSEMBLY

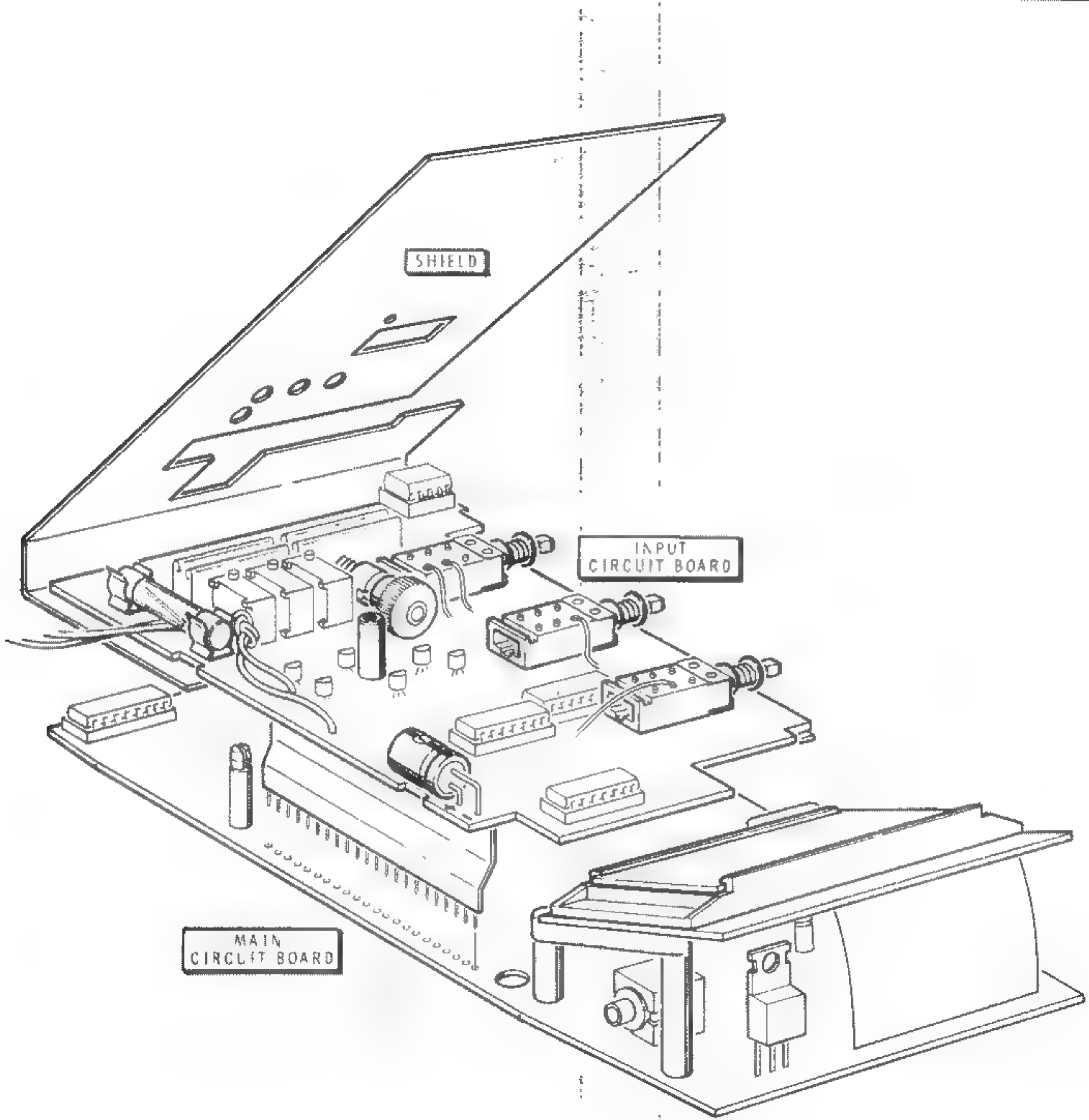
Refer to Pictorial 4-1 (Illustration Booklet, Page 5) for the following steps

(U) Refer to Detail 4-1A and match the pins at the free end of the 16-wire ribbon cable with the corresponding row of holes from the lettered side of the main circuit board. Be sure the cable is fully seated against the circuit board and all the pins protrude through the circuit board. Then solder all the pins to the circuit board and cut off the excess pin lengths.

(J) Refer to Detail 4-1B and match the pins at the free end of the 22-wire ribbon cable with the corresponding row of holes from the lettered side of the main circuit board. Be sure the cable is fully seated against the circuit board and all the pins protrude through the circuit board. Then solder all the pins to the circuit board and cut off the excess pin lengths.



Detail 4-1A



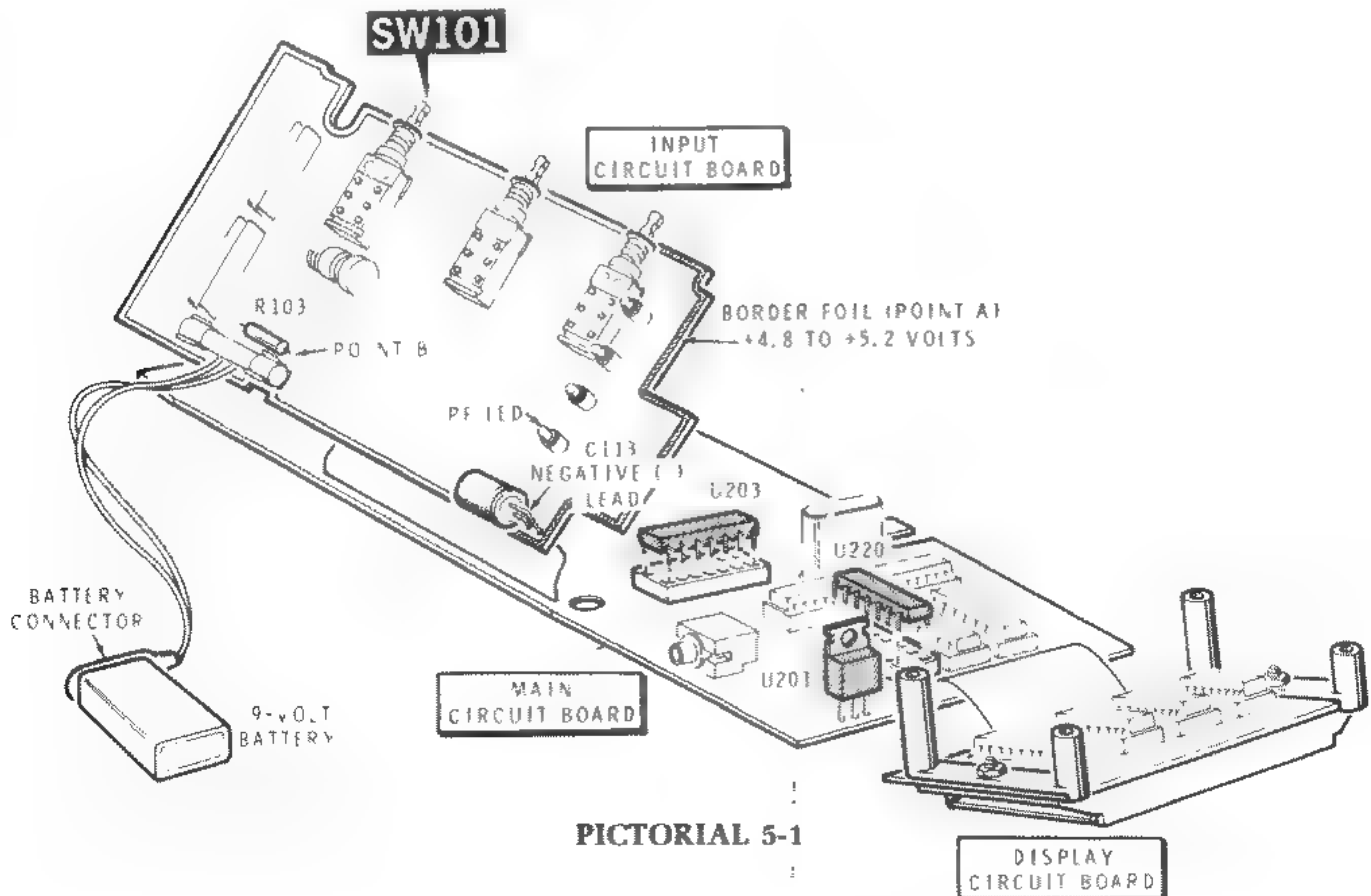
Detail 4-1B

INITIAL TESTS

The purpose of this section of the Manual is to make sure your Capacitance Meter functions properly and will not be damaged as the result of a wiring error. If you have any difficulty in the following steps, depress the POWER switch to off and disconnect the battery. Then refer to the "In Case of Difficulty" section on Page 59.

Refer to Pictorial 5-1 to identify the points on the circuit boards called out in the following steps.

- (✓) Make sure POWER switch SW101 is in the off (out) position.
- (✓) Plug the battery connector onto the 9-volt battery (not supplied).



NOTE: If a high impedance (10,000 Ω /V or greater) voltmeter is available, make the following "Voltage Checks." If a voltmeter is not available, however, perform the steps under "Heat Checks" instead.

VOLTAGE CHECKS

These voltage checks are made to make sure the 5-volt regulator (U201) is functioning properly.

(✓) Connect the common lead of your voltmeter to the negative (-) lead of capacitor C113 on the input circuit board.

(✓) Set your voltmeter to the lowest range capable of measuring +5 volts DC.

(✓) Place switch SW101 in the on (in) position. The display should present some reasonable reading (not necessarily 00.0 at this time). Also the pF LED annunciator should be lit.

(✓) 1. Connect the voltmeter test lead to the indicated border foil (point A) on the **top side** of the input circuit board. The meter reading should be +4.8 to +5.2 volts.

() 2. If the voltage in step 1 is correct, connect the voltmeter test lead to the indicated lead of resistor R103 (point B). The meter reading should be +2 volts DC \pm 10%.

() Place switch SW101 in the off (out) position.

NOTE: Be sure to match the pin 1 end of each of the following integrated circuits with the index marks on the circuit board

(✓) U203: Install a 74LS90 IC (#443-813) at U203 on the main circuit board

() U220: Install a 74LS90 IC (#443-813) at U220 on the main circuit board.

(✓) Place switch SW101 in the on (in) position.

(✓) Repeat steps 1 and 2 above.

(✓) Place switch SW101 in the off (out) position.

Proceed to "General Assembly, Cont'd."

HEAT CHECKS

Perform these checks to make sure the 5-volt regulator (U201) is functioning properly.

() 1. Place POWER switch SW101 in the on (in) position. The display should present a reasonable reading (not necessarily 00.0 at this time). Also, the pF LED annunciator should be lit with average intensity. If so, leave the Capacitance Meter on for a few seconds. Then check the components, especially 5-volt regulator U201, for excessive heating.

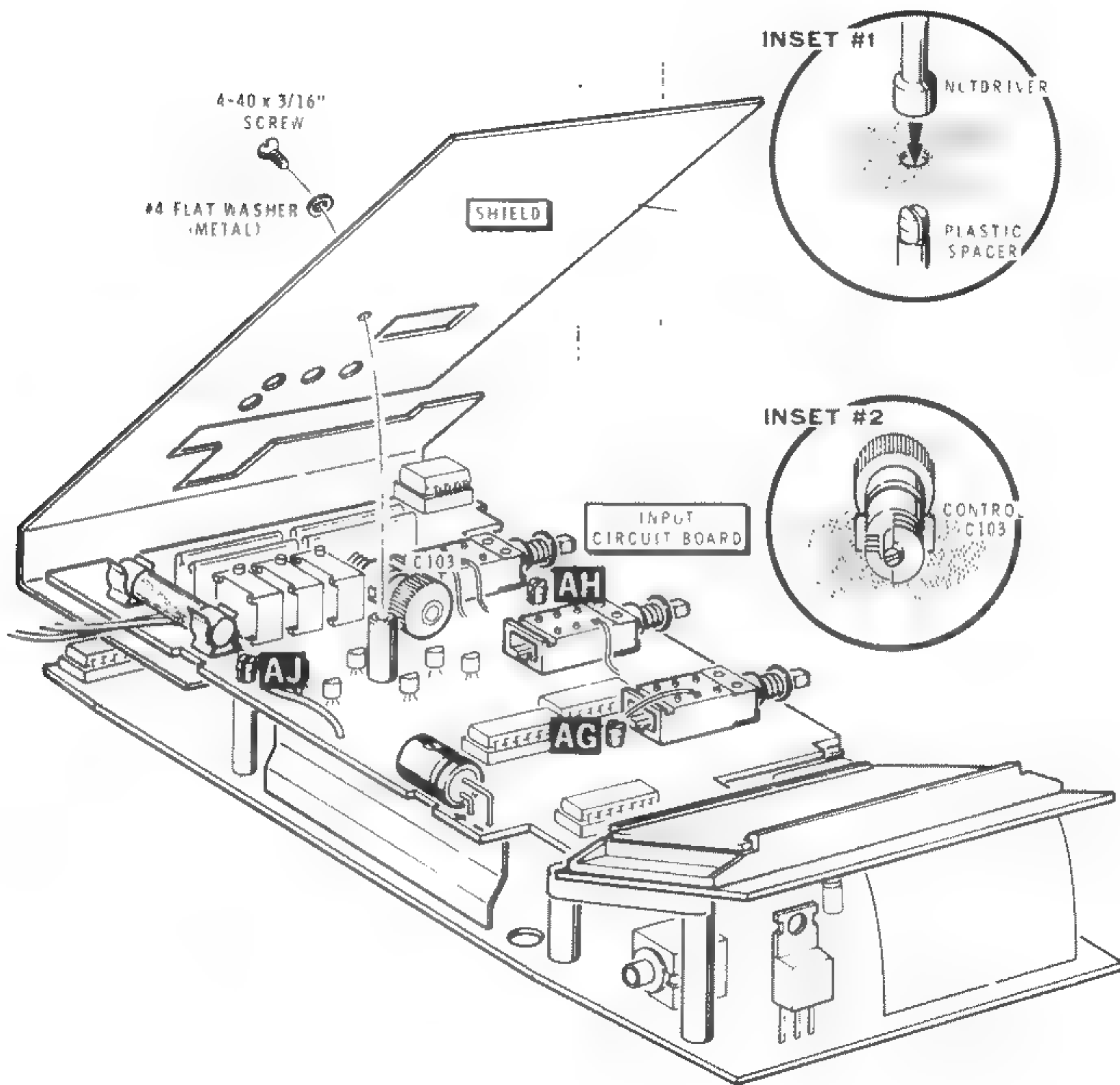
(✓) 2. Place switch SW101 in the off (out) position.

NOTE: Be sure to match the pin 1 end of each of the following integrated circuits with the index marks on the circuit board.

() U203: Install a 74LS90 IC (#443-813) at U203 on the main circuit board.

() U220: Install a 74LS90 IC (#443-813) at U220 on the main circuit board

() Repeat steps 1 and 2 above.



PICTORIAL 5-2

GENERAL ASSEMBLY, Cont'd.

Refer to Pictorial 5-2 for the following steps

Install the input circuit board on the plastic spacers on the main circuit board as follows

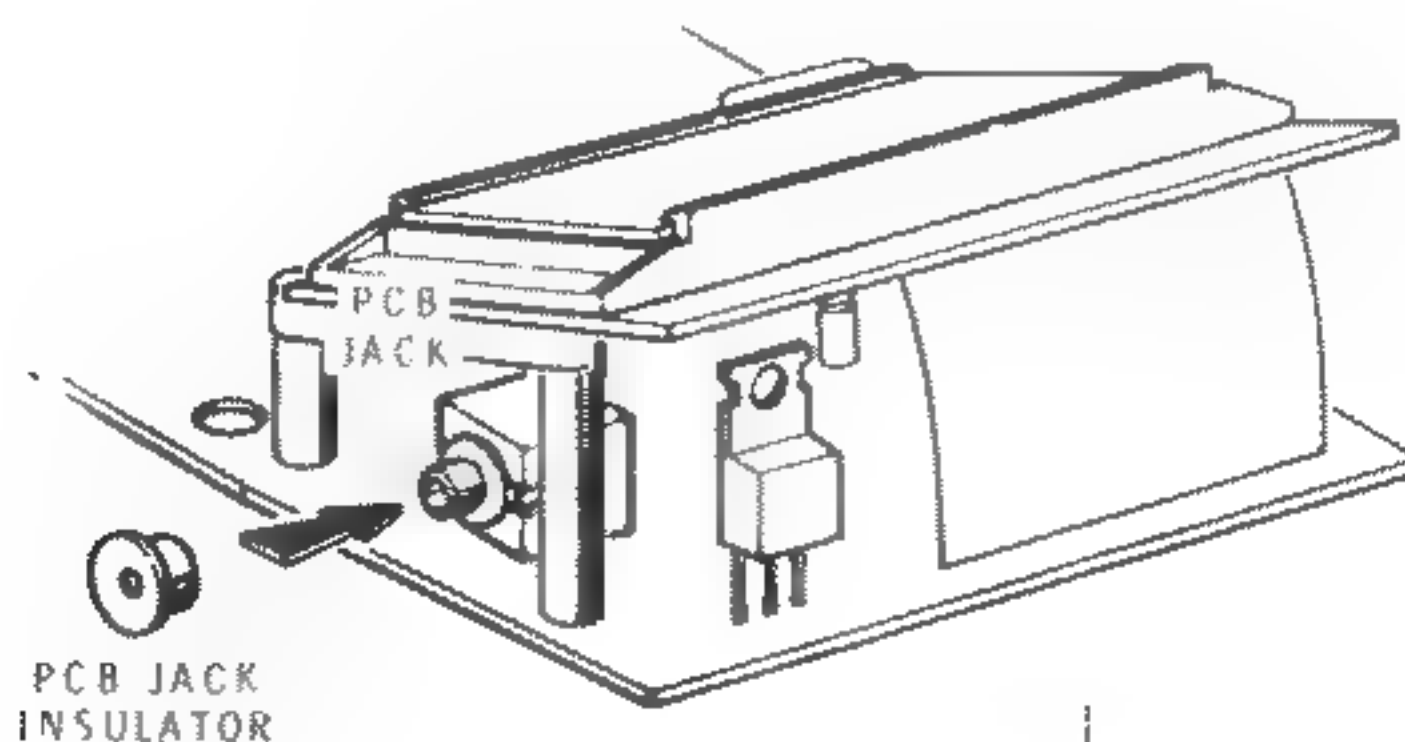
- (✓) Align hole A] in the input circuit board with the corresponding plastic spacer on the main circuit board. Refer to inset drawing #1 on Pictorial 5-2 and carefully press on the input circuit board, using a nut driver or other blunt tool centered over the spacer, until the input circuit board snaps in place. Be careful not to damage the foil on the top of the circuit board
- () Repeat the above step for holes AG and AH in that order

- () Refer to inset drawing #2 on Pictorial 5-2 and set control C103 so it is about 50% engaged as shown.

- (✓) Fold the shield over the switches. Secure the shield to the metal spacer mounted on the input circuit board. Use a #4 flat washer and a 4-40 × 3/16" flat head screw. Do NOT overtighten the screw

- () Refer to Detail 5-2A and press the PCB jack insulator onto the PCB jack as shown.

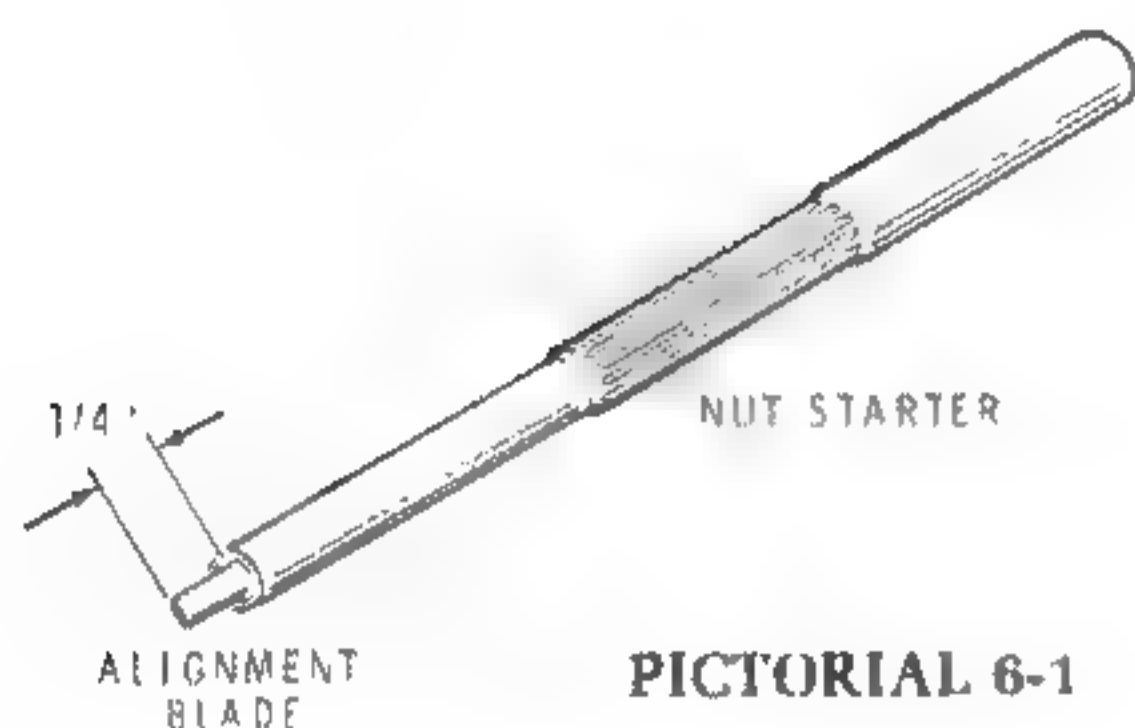
Proceed to "Calibration."



Detail 5-2A

CALIBRATION

CALIBRATION PREPARATION



Refer to Pictorial 6-1 for the following steps

- (✓) Locate the alignment blade (#490-193). This is the alignment tool tip. With pliers, insert the tip of the blade into the small end of the nut starter so the narrow end extends 1/4" from the end of the starter.

Refer to Pictorial 6-2 (Illustration Booklet, Page 5) to find the location of the controls referred to in the following steps

- (✓) Use the alignment tool to set calibration controls R117, R123, and R129 to their fully counterclockwise position (twenty turns or until you hear a very faint "click")

NOTES

1. New Capacitance Meters may exhibit a small amount of calibration drift due to "component aging." Therefore, we suggest that you recalibrate your Capacitance Meter

after an initial period of use; 30 days, for example. You may also wish to recalibrate your Capacitance Meter regularly at six-to-twelve-month intervals, or as required, to insure optimum accuracy during use

2. If you do not obtain the correct indication in any of the following steps, refer to the "In Case of Difficulty" section. Locate and repair any problem before you continue with the calibration.
3. We recommend that you use battery power when you calibrate this Meter.

- (✓) Make sure the battery eliminator is disconnected from your Capacitance Meter

NOTE: Two methods of calibration are provided in this section of the Manual. The first method (Supplied Standards Method) uses the references supplied with this kit. The second method (on Page 46) uses laboratory-grade standard references

To perform the calibration with laboratory-grade standard references, you will need a capacitance measurement standard having 5 times the accuracy of the desired calibration accuracy. Also, these capacitors should be of the type that will generally be measured on each of the three ranges of your Capacitance Meter. The capacitors used as standards should have minimum leakage, series resistance, inductance, voltage coefficient, dissipation, and good temperature stability.

Choose one of the calibration methods and perform the steps for that method only.

SUPPLIED STANDARDS METHOD

Refer to Pictorial 6-2 for the following steps

- (✓) Locate the calibration package (#100-1779) and remove the three capacitors. They will be used in the following steps. Be sure to save the package for future calibration information.
- (✓) Place POWER switch SW101 in the on (in) position.

NOTE: Make sure you perform the following calibration steps within the temperature range specified on the envelope for the calibration package or in the Specifications section of this Manual

- (✓) Install capacitor A from the calibration package in your Capacitance Meter. The nF indicator should light. Then adjust the A range calibration control (R129) for the value indicated (on the envelope) for that capacitor (145.8)
- (✓) Remove capacitor A from the Meter and adjust coarse ZERO control C104 for a reading of "00 0"
- (✓) Reinstall capacitor A and readjust the A range calibration control for the value indicated for that capacitor
- (✓) Again remove capacitor A from the Meter and adjust coarse ZERO control C104 for a reading of "00 0." NOTE: You should now be able to adjust fine ZERO control C103 to obtain a display reading within 1 count of "00.0" (00.1pF)

without being close to the maximum or minimum value for capacitor C103. If you cannot obtain a display reading of "00 0" after calibrating the A range by adjusting C103 and/or C104, refer to "In Case of Difficulty"

- (✓) Install capacitor B from the calibration package in your Capacitance Meter. Be sure to observe the polarity marking(s) of this capacitor the μ F capacitor should light. Then adjust the B range calibration control (R123) for the value indicated for that capacitor. (140.8)

- (✓) Remove capacitor B from the Meter

- (✓) Install capacitor C from the calibration package in your Capacitance Meter. Be sure to observe the polarity marking(s) of this capacitor. Then adjust the C range calibration control (R117) for the value indicated for that capacitor. (0951)

- (✓) Remove capacitor C from the Meter.

- (✓) Place POWER switch SW101 in the off (out) position.

- (✓) Return the three calibration capacitors to their envelope. Save this package for possible future use.

This completes the "Calibration" of your Capacitance Meter. However, after it has been in use for some time - 30 days for example - you may wish to touch up the calibration to remove any small "aging" drift. Proceed to "Final Assembly"

LABORATORY STANDARDS METHOD

Make sure your calibration standards are at least 5 times more accurate than the calibration accuracy you desire. For example, to obtain an accuracy of $\pm .25\%$, the calibration standards must be accurate within $\pm .05\%$.

- () Select a capacitor standard for each of the three calibration ranges of your Capacitance Meter. NOTE: $.15\ \mu\text{F}$, $150\ \mu\text{F}$, and $1000\ \mu\text{F}$ are suitable values.
- () Use a capacitance bridge to accurately measure the value of each of the three capacitor standards selected under the conditions selected below

IT-2250 RESISTANCE RANGE*	BRIDGE EXCITATION FREQ. (Hz)	BRIDGE CURRENT (mA)	BRIDGE BIAS VOLTAGE (VDC)
A	1000	20	15
B	300	20	15
C	100	20	15

*See Appendix on Page 77

Refer to Pictorial 6-2 for the following steps.

- () Place POWER switch SW101 in the on (in) position

NOTE: Make sure you perform the following calibration steps within the temperature range given in the Specifications section of this Manual.

- () Install capacitor A in your Capacitance Meter. Then adjust the A range calibration control (R129) for the value measured for that capacitor.
- () Remove capacitor A from the Meter and adjust coarse ZERO control C104 for a display reading of "00.0"

- () Reinstall capacitor A and readjust the A range calibration control for the value measured for that capacitor.

- () Again remove capacitor A from the Meter and adjust coarse ZERO control C104 for a reading of "00.0." NOTE: You should now be able to adjust fine ZERO control C103 to obtain a display reading within 1 count of "00.0" (00.1pF) without being close to the maximum or minimum value for capacitor C103. If you cannot obtain a display reading of "00.0," after calibrating the A range by adjusting C103 and/or C104, refer to "In Case of Difficulty."

- () Install capacitor B in your Capacitance Meter. Be sure to observe the polarity marking(s) of this capacitor. Then adjust the B range calibration control (R123) for the value measured for this capacitor.

- () Remove capacitor B from the Meter.

- () Install capacitor C in your Capacitance Meter. Be sure to observe the polarity marking(s) of this capacitor. Then adjust the C range calibration control (R117) for the value measured for this capacitor.

- () Remove capacitor C from the Meter.

- () Place POWER switch SW101 in the off (out) position.

- () Save the three calibration capacitors, with a record of their measured values, for possible future use

This completes the "Calibration" of your Capacitance Meter. However, after it has been in use for some time — 30 days, for example — you may wish to touch up the calibration to remove any small "aging" drift. Proceed to "Final Assembly."

FINAL ASSEMBLY

PARTS LIST

Check each of the remaining parts against the following list. The key numbers correspond to the numbers on the "Final Assembly Parts Pictorial" (Illustration Booklet, Page 6).

To order a replacement part, always include the PART NUMBER. Use the Parts Order Form furnished with this kit. If a Parts Order Form is not available, refer to "Replacement Parts" inside the rear cover of this Manual. For prices, refer to the separate "Heath Parts Price List."

KEY No	HEATH Part No.	QTY	DESCRIPTION	CIRCUIT Comp No
-----------	-------------------	-----	-------------	--------------------

HARDWARE

A1	250-188	4	#4 × 3/8" self-tapping screw	
A2	250-1300	3	#6 × 5/8" self-tapping screw	
A3	253-43	4	#5 fiber flat washer	

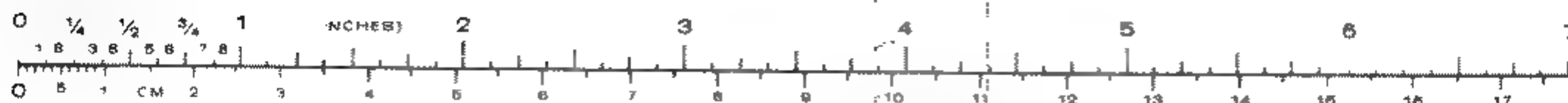
CASE PARTS

	305-96		Case parts consisting of:	
B1	92-722	1	Case bottom	
B2	92-723	1	Case top	
B3	92-736	1	Switch cover plate	

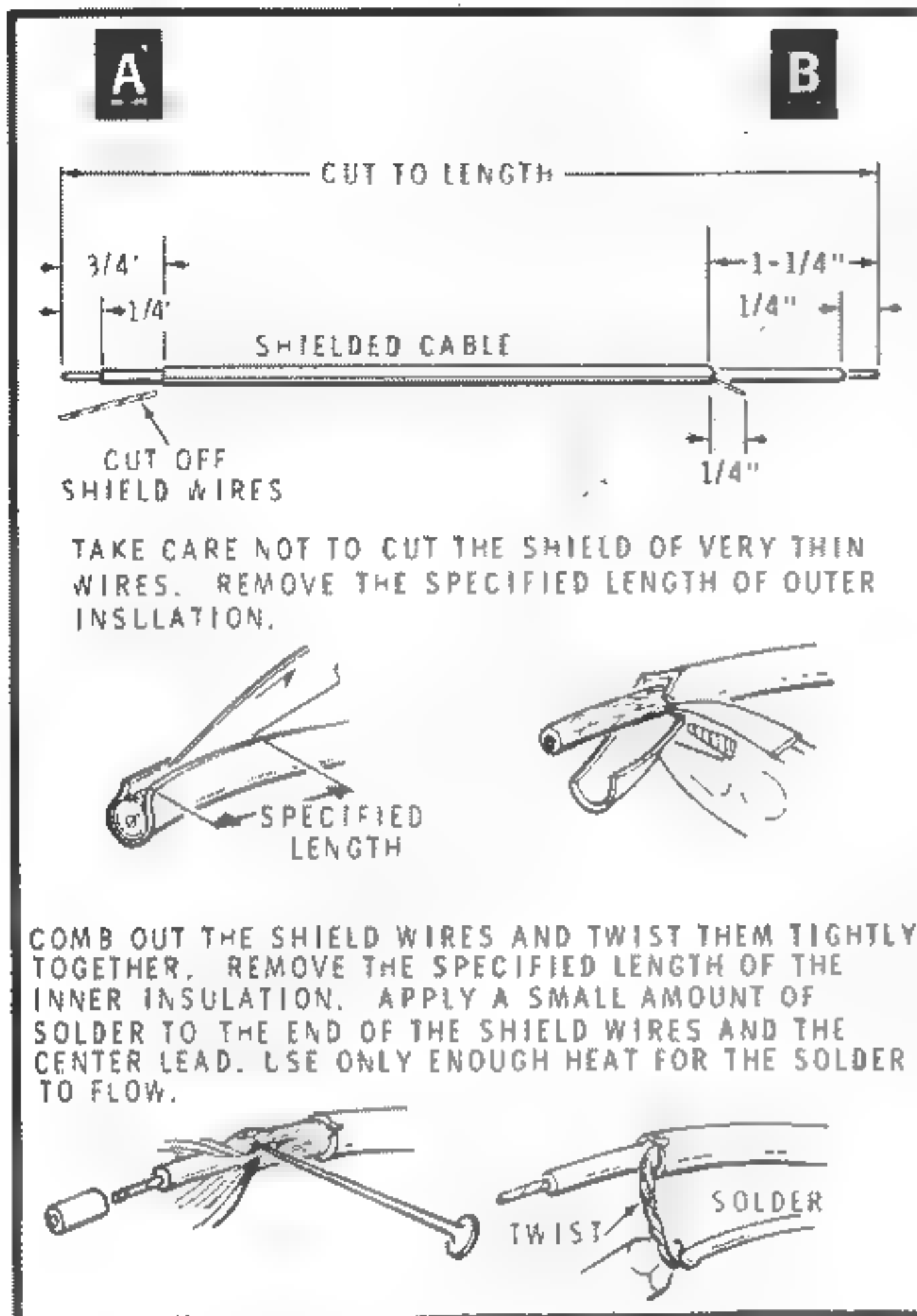
KEY No	HEATH Part No.	QTY	DESCRIPTION	CIRCUIT Comp. No.
-----------	-------------------	-----	-------------	----------------------

MISCELLANEOUS

C1	73-34	2	Red alligator clip insulator	
C1	73-159	2	Black alligator clip insulator	
C2	73-142	2	Rubber gasket	
	85-2536	1	Printed circuit card connector	
C3	211-87	1	Bail	
C4	260-16	4	Alligator clip	
	343-12	4	Shielded cable	
C5	354-5	2	Cable tie	
C6	462-1105	3	Knob	



STEP-BY-STEP ASSEMBLY



Detail 7-1A

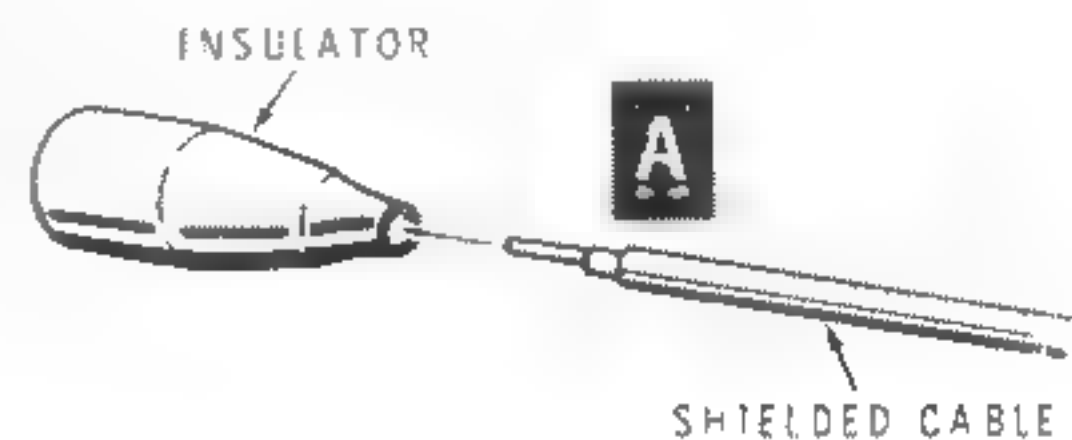
REMOTE CABLE

Refer to Pictorial 7-1 (Illustration Booklet, Page 6) for the following steps

1. Refer to Detail 7-1A and prepare two 11" and two 12" lengths of shielded cable.
2. Refer to Detail 7-1B, and insert end A of a 11" shielded cable through a black alligator clip insulator.
3. Similarly, insert end A of the other 11" shielded cable through the remaining black alligator clip insulator.

Refer to Detail 7-1B, and insert end A of a 12" shielded cable through a red alligator clip insulator.

Similarly, insert end A of the other 12" shielded cable through the remaining red alligator clip insulator.

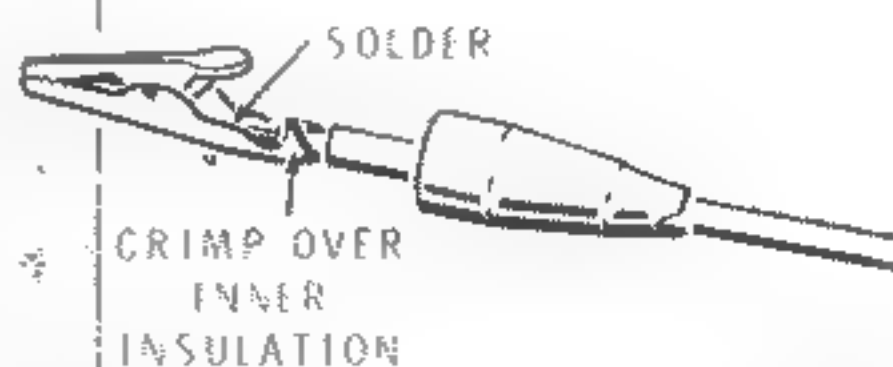
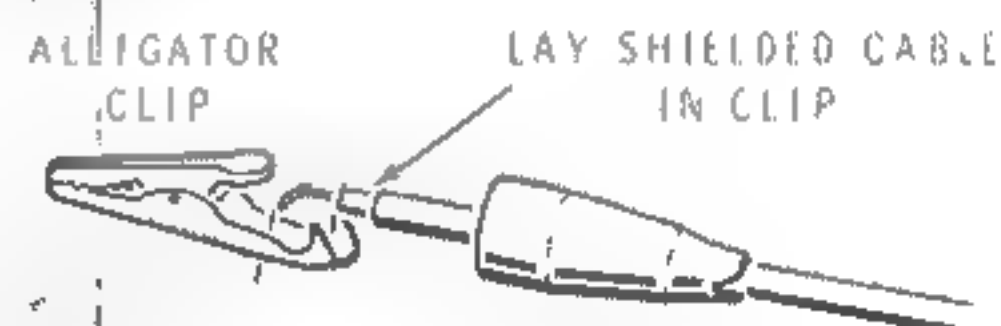


Detail 7-1B

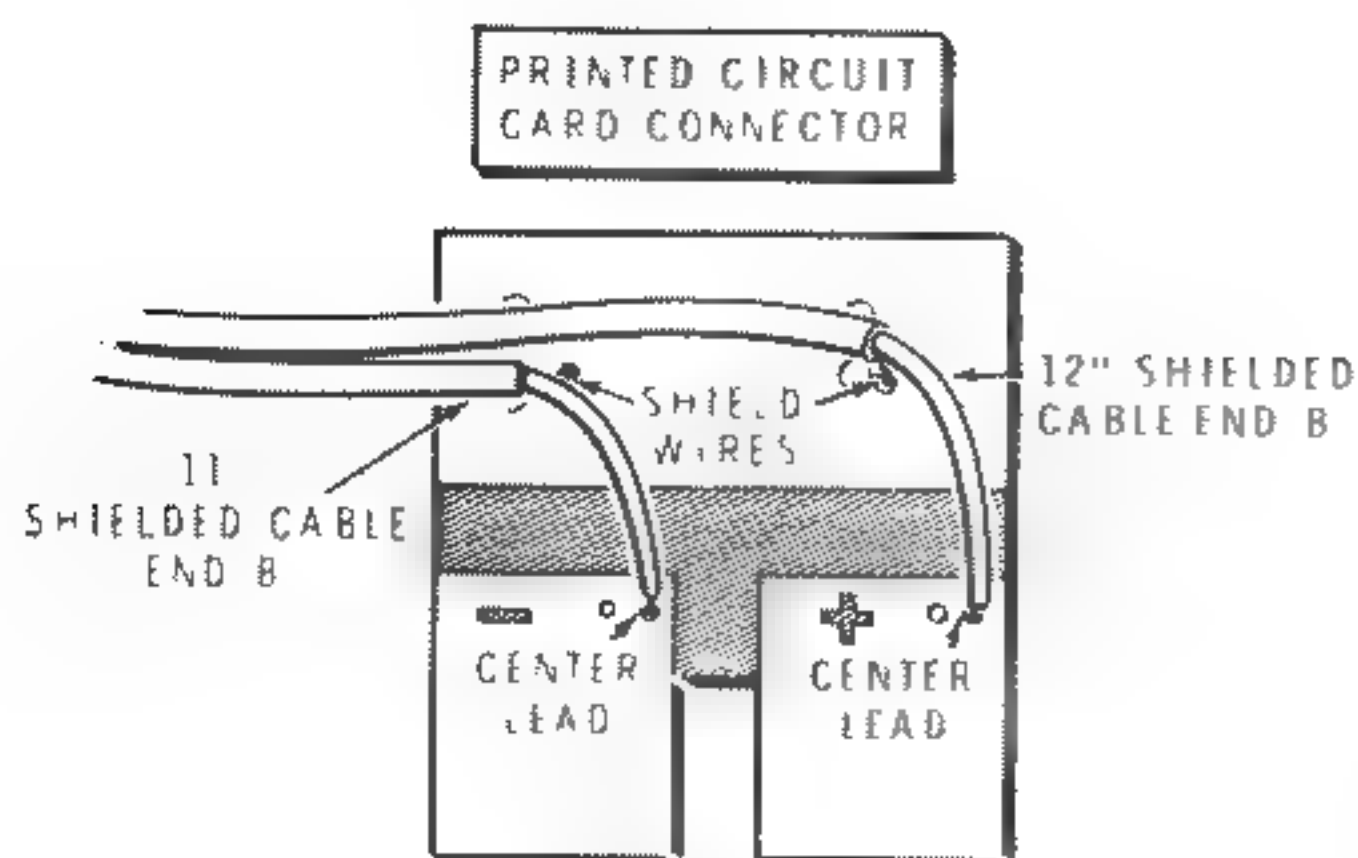
Refer to Detail 7-1C and install an alligator clip on end A of any one of the four shielded cables

Similarly, install an alligator clip on end A of each of the three remaining shielded cables.

After the solder has cooled, push each of the four alligator clip insulators down over the respective alligator clips as shown in the Pictorial



Detail 7-1C



Detail 7-1D

Position the printed circuit card connector as shown in Detail 7-1D as shown.

Refer to Detail 7-1D and connect end B of an 11" shielded cable to the printed circuit card connector as follows. Solder each lead as you connect it and cut off any excess lead length.

Center lead to the indicated hole (near the - sign).

NOTE: In the following step, and in several others on this page, you may find the shield wires of cables too large to insert in the circuit board holes. If this occurs, trim the shield wires thinner with diagonal cutters so the shield will fit in the hole.

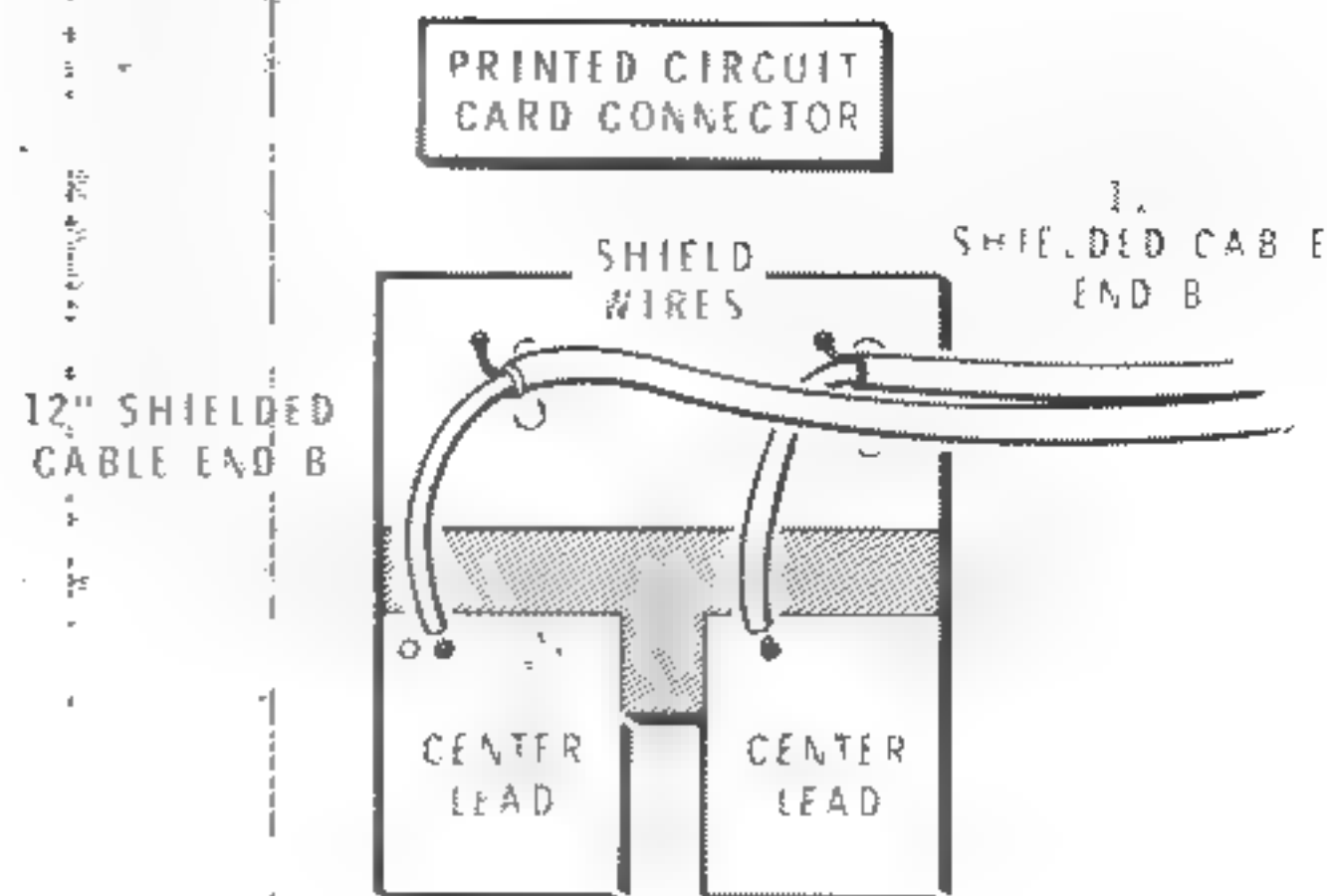
Shield wires to the indicated hole.

Refer to Detail 7-1D and connect end B of a 12" shielded cable to the printed circuit card connector as follows. Solder each lead as you connect it and cut off any excess lead length.

Center lead to the indicated hole (near the + sign).

Shield wires to the indicated hole.

Turn the printed circuit card connector over as shown in Detail 7-1E.



Detail 7-1E

Refer to Detail 7-1E and connect end B of the remaining 12" shielded cable to the printed circuit card connector as follows. Solder each lead as you connect it and cut off any excess lead length.

Center lead to the indicated hole (near the + sign).

Shielded wires to the indicated hole.

Refer to Detail 7-1E and connect end B of the remaining 11" shielded cable to the printed circuit card connector as follows. Solder each lead as you connect it and cut off any excess lead length.

Center lead to the indicated hole (near the - sign).

Shield wires to the indicated hole.

Refer to the inset drawing on Pictorial 7-1 and with a cable tie, secure the four cables to the printed circuit card connector at the location shown.

Similarly, use the remaining cable tie and secure the two shielded cables at the other location on the printed circuit card connector.

Set the remote cable aside.

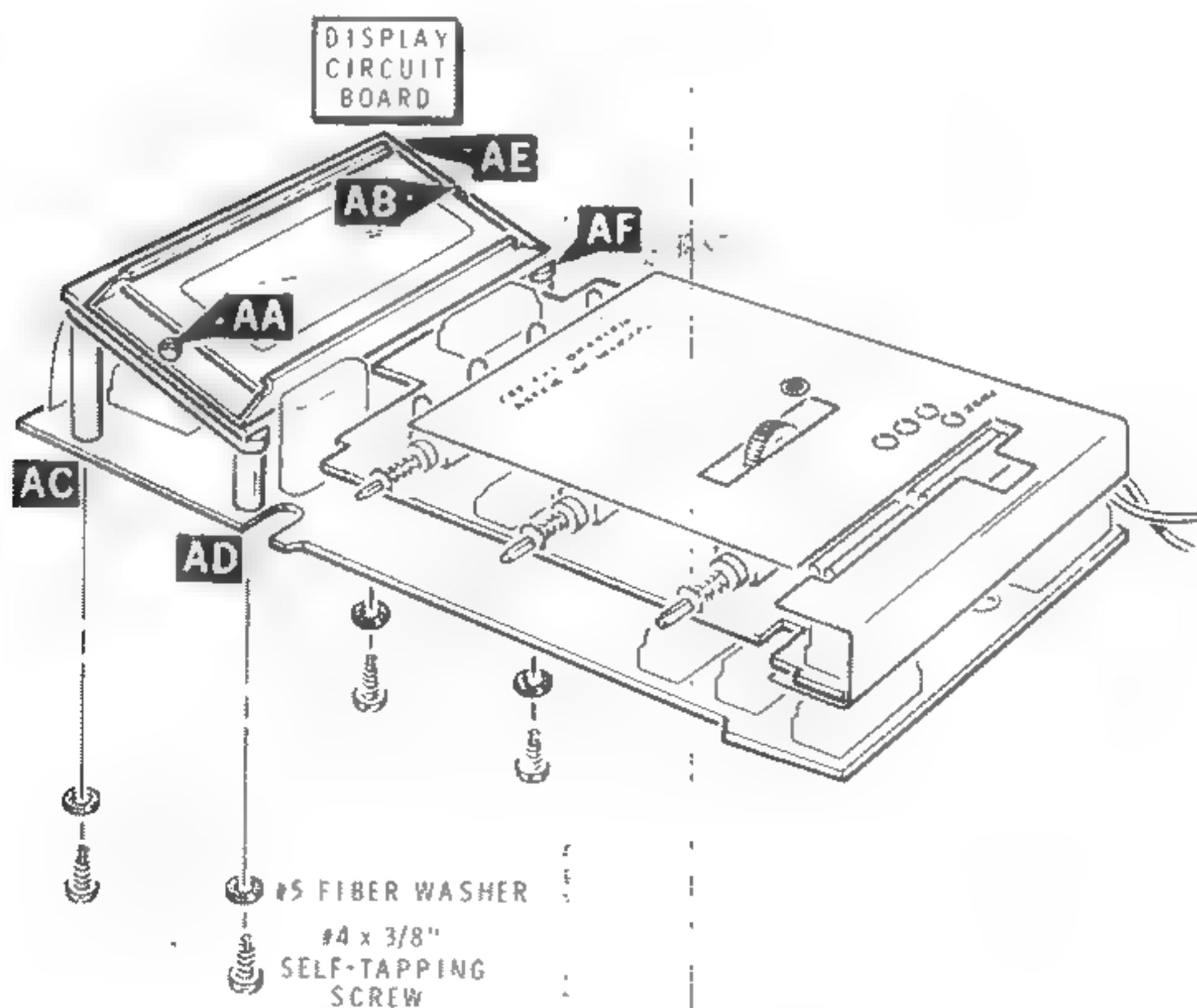


CASE

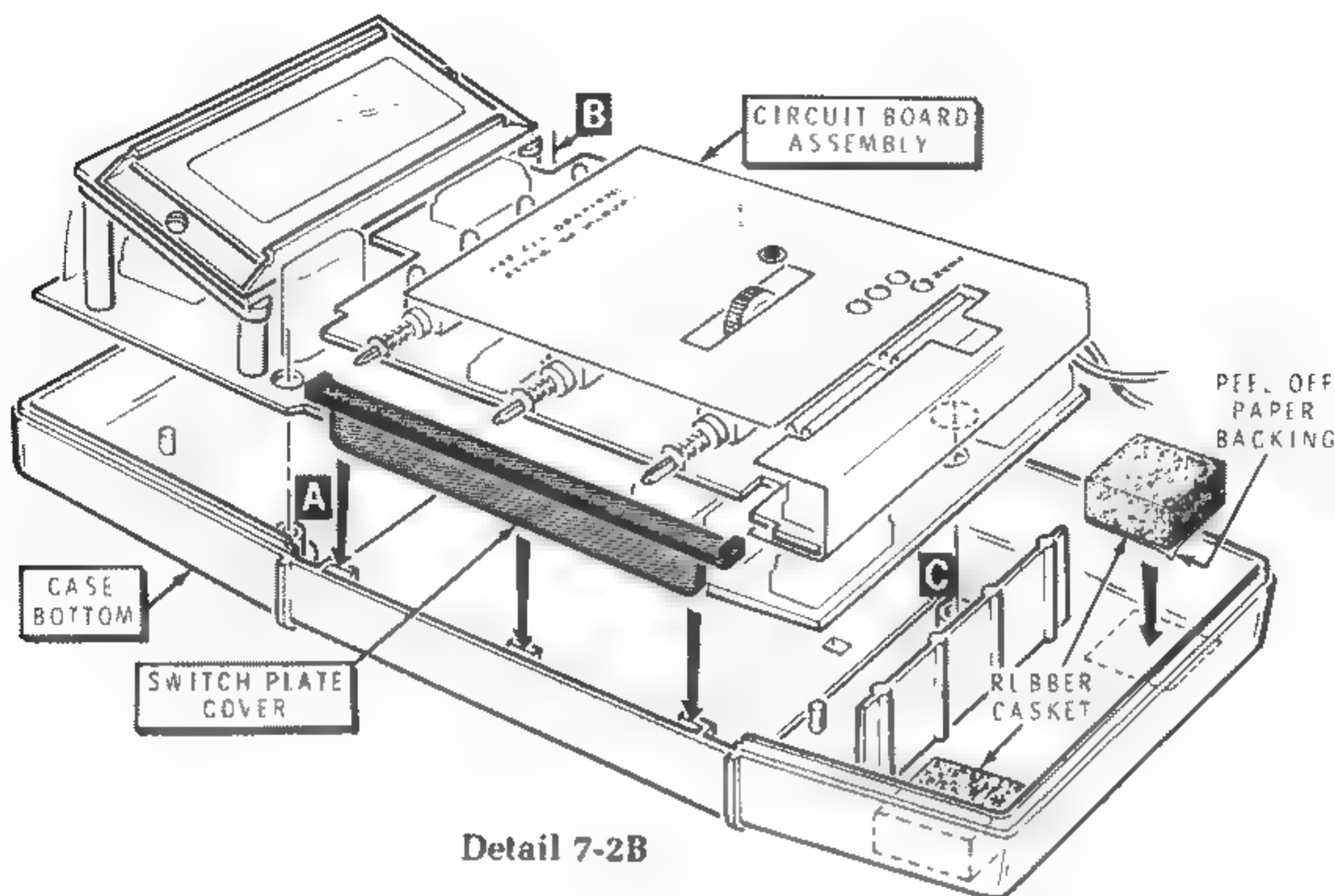
Refer to Pictorial 7-2 (Illustration Booklet, Page 6) for the following steps:

NOTE: For easier alignment, when you perform the next step, you may wish to loosen the hardware at AA and AB. After you complete the step, be sure to re-tighten the hardware

- (✓) Refer to Detail 7-2A and mount the display circuit board assembly to the main circuit board. Use #5 fiber flat washers and #4 × 3/8" self-tapping screws at AC, AD, AE, and AF. Do NOT overtighten the screws

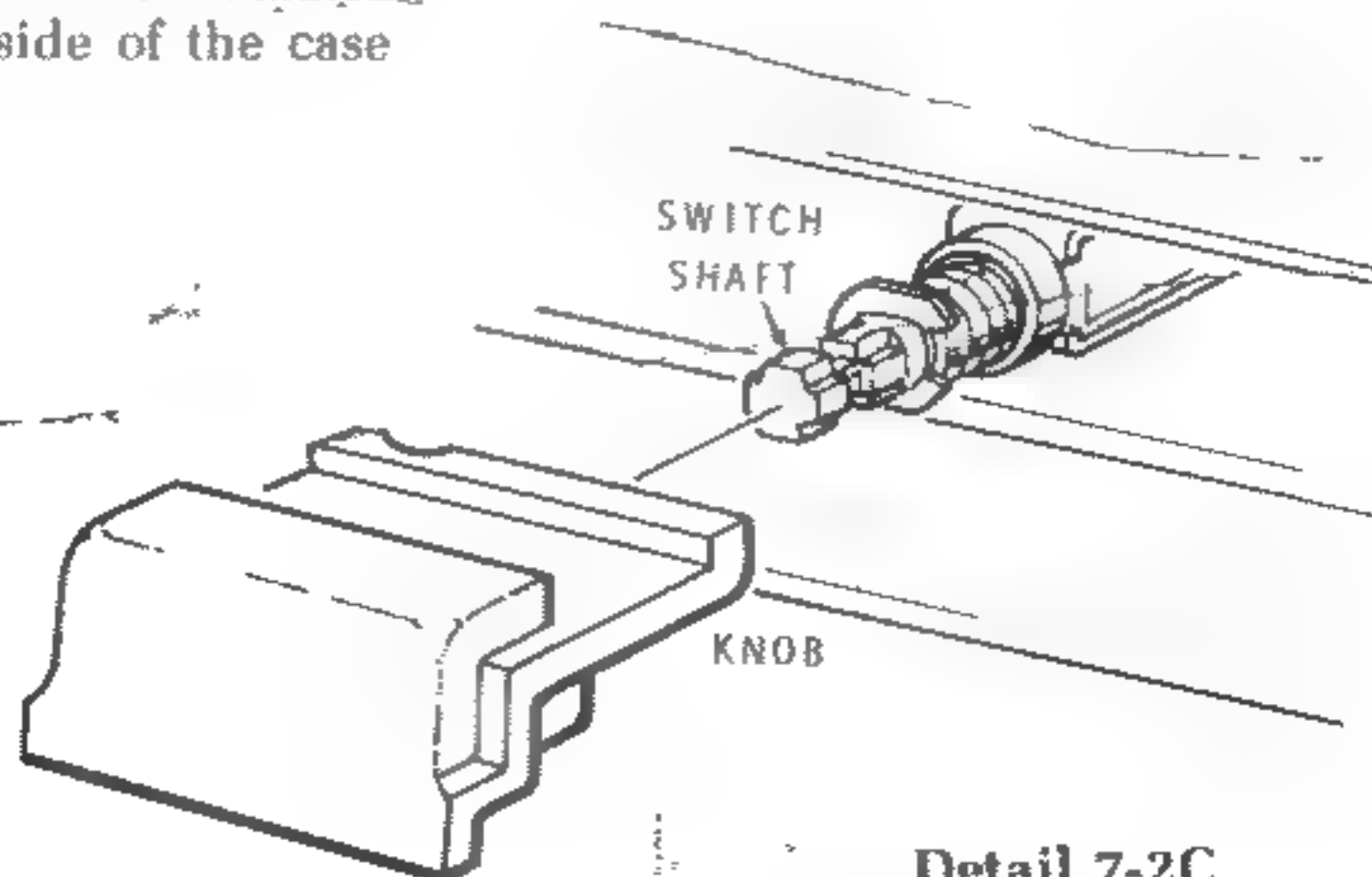


Detail 7-2A

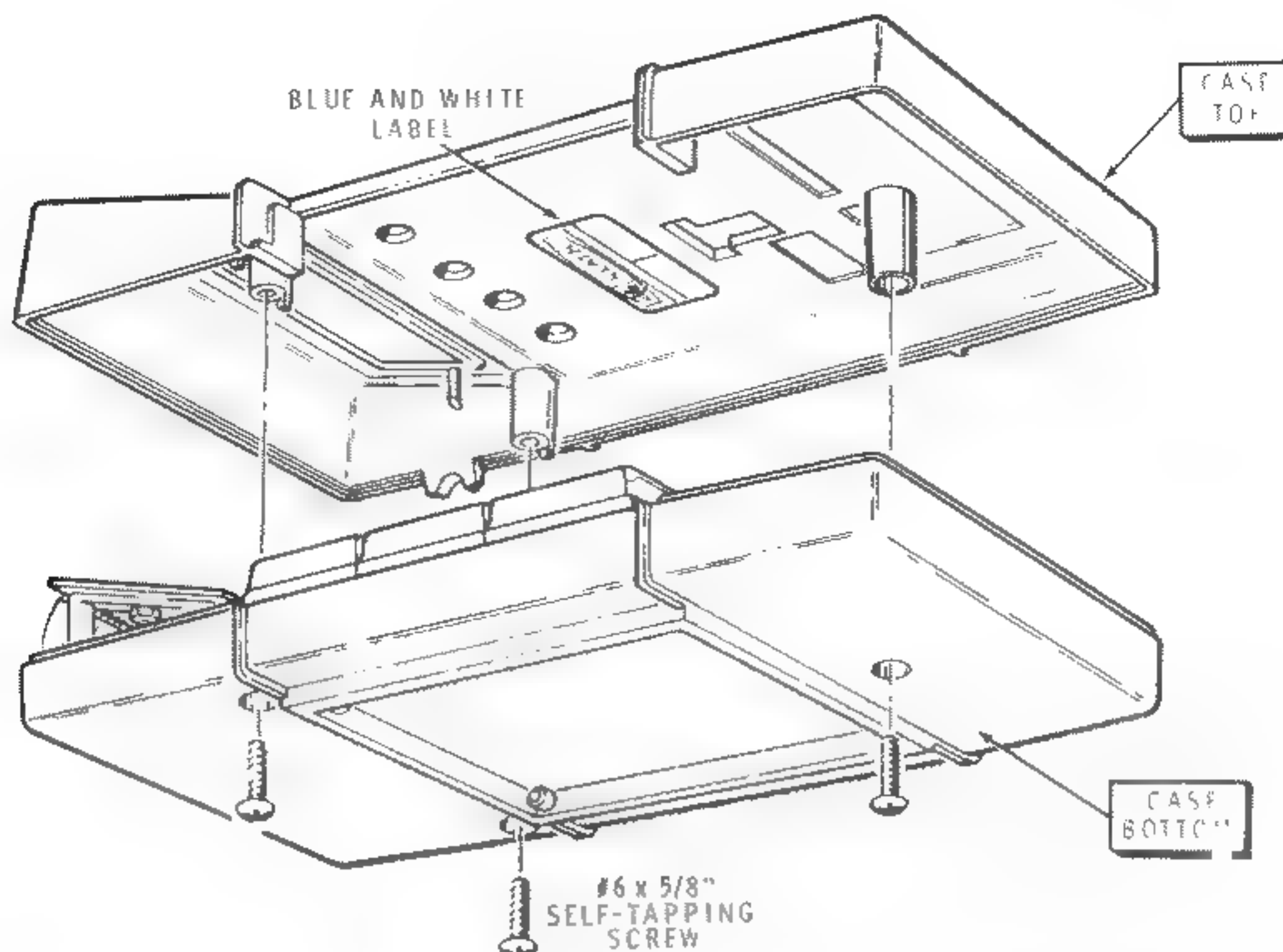


Detail 7-2B

- (✓) Peel the backing paper from two rubber gaskets. Then refer to Detail 7-2B and press these gaskets to the inside of the case bottom at the locations shown.
- (✓) Refer again to Detail 7-2B and slide the switch plate cover into the slots in the side of the case bottom as shown.
- (✓) Refer again to Detail 7-2B and position the circuit board assembly into the case bottom. Line up the bosses at A, B, and C in the case bottom with the corresponding holes in the circuit board. Then push the circuit board assembly down over the bosses. Make sure the insulator on the PCB jack is on the inside of the case bottom.
- (✓) Refer to Detail 7-2C and place a knob next to a switch shaft as shown. Line up square hole in the knob with the end of the shaft. Then push the knob all the way onto the shaft.
- (✓) Similarly, install a knob on each of the two remaining switch shafts.
- (✓) Install the battery in the small compartment in the case bottom. Make sure you dress the two wires from the battery connector inside the case as shown in the Pictorial.



Detail 7-2C



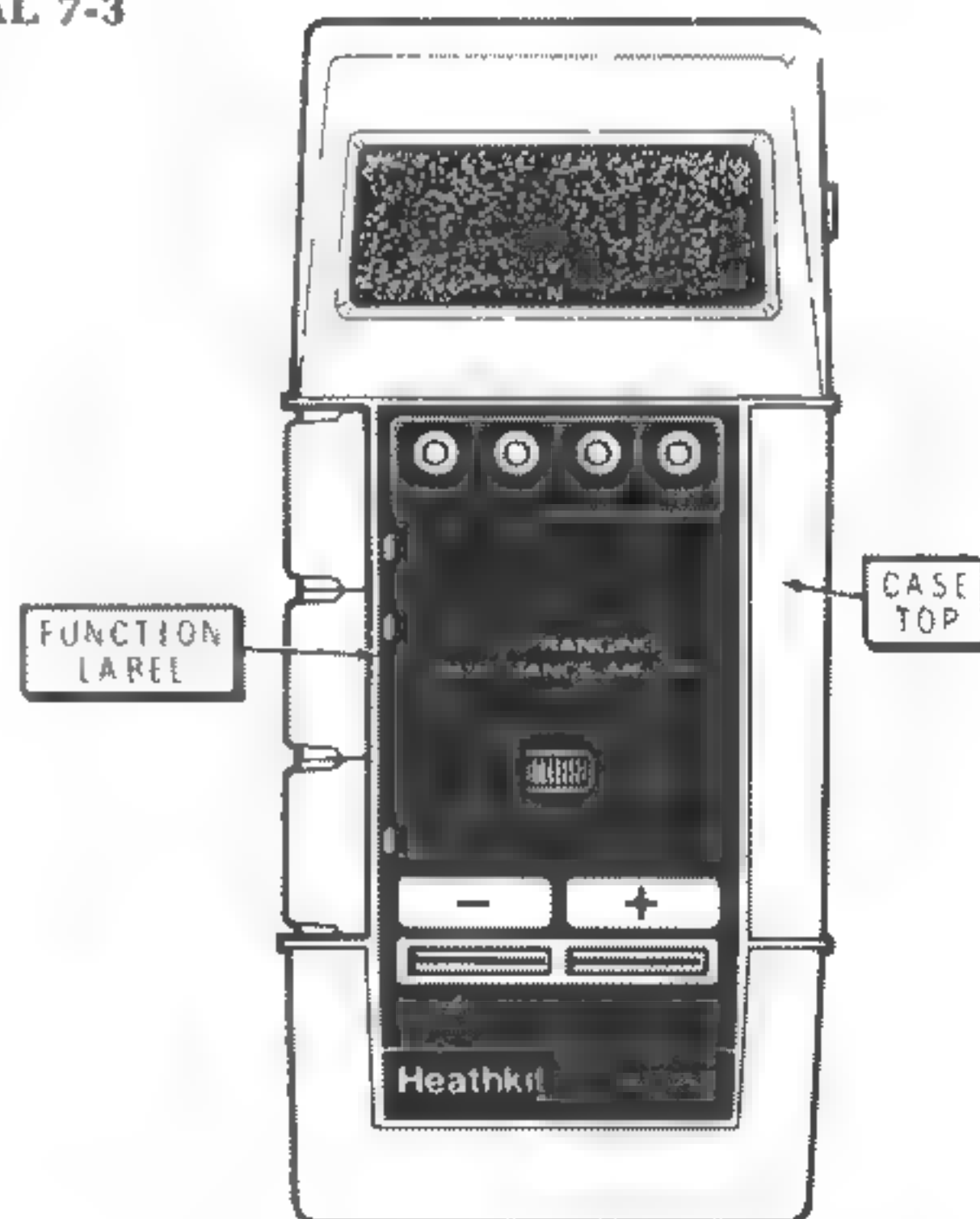
PICTORIAL 7-3

Refer to Pictorial 7-3 for the following steps

- (1) Refer to Detail 7-3A and carefully apply the Function label to the case top. First, if necessary, remove the cutout portions of the label. Then peel away the protective backing paper. Finally, press the label into place on the case top.

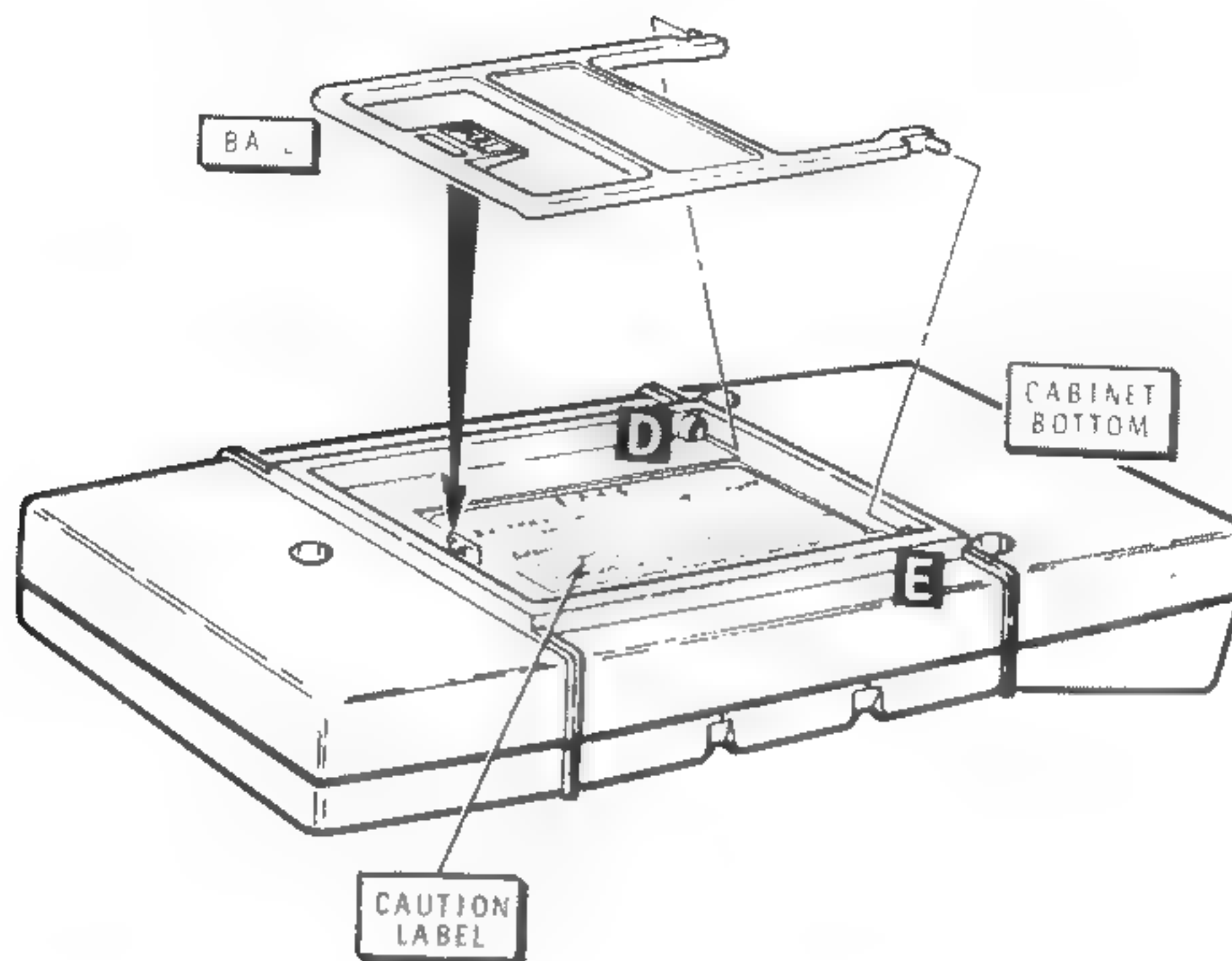
NOTE: The blue and white label that you will install in the following step shows the Model number and Production Series number of your kit. Refer to these numbers in any communications you have with the Heath Company about this kit.

- (2) Carefully peel away the paper backing from the blue and white label. Then press the label to the inside of the case top at the location shown.
- (3) Position the case top over the case bottom as shown in the Pictorial. Press the case halves together and make sure the printed border on the display window is centered in the case top window opening. You may have to loosen the two 4-40 \times 3/8" screws on the display circuit board assembly to properly position the display circuit board. Be sure to retighten the two screws.



Detail 7-3A

- (4) Being careful not to pinch any wires or the PCB jack insulator between the case halves, secure the case halves together with three #6 \times 5/8" self-tapping screws.



PICTORIAL 7-4

Refer to Pictorial 7-4 for the following steps.

- (A) Position the cabinet bottom as shown.

NOTE: In the following step, be sure you position the label as shown in the Pictorial before you press the label in place.

- (B) Carefully peel away the backing paper from the Caution label. Then press the label into the recessed area in the case bottom.

- (C) Install the bail in the recessed area in the case bottom by first pressing the open end of the bail slightly together with one hand. Line up the ends of the bail with holes D and E in the case bottom. Then release the pressure on the bail. Finally, push the bail so it pivots into the recessed area and is held in place by the catch.

This completes the assembly of your Capacitance Meter.

OPERATION

GENERAL

This portion of the Manual is divided into three parts. The first part, "General," provides information concerning various precautions you must observe when using the Capacitance Meter. The second part, "Operating Characteristics," includes operating information that applies to the various functions of the Capacitance Meter. The third part, "Measurements," provides specific operating instructions for the Capacitance Meter.

NOTE: Be sure you read all of the "General" and "Operating Characteristics" before you use the Capacitance Meter.

Refer to Pictorial 8-1 (Illustration Booklet, Page 7) for a brief description of each switch and jack.

The front of the Capacitance Meter has a standard international operator warning. It is:



This symbol advises the operator to familiarize himself with the operation section of this Manual.

OPERATING PRECAUTION

ALWAYS DISCHARGE A CAPACITOR TO BE MEASURED BEFORE YOU INSERT IT INTO THE CAPACITANCE METER. Although your Capacitance Meter features a solid-state input protection circuit, in addition to a fuse, always discharge a capacitor before making a measurement. NEVER APPLY A VOLTAGE TO THE INPUT OF THE CAPACITANCE METER.

LIQUID CRYSTAL DISPLAY

The liquid crystal display (LCD) is a rugged and reliable device that should provide years of service. You can extend the display lifetime by observing the following practices.

- A. Protect the display from extended exposure to bright sunlight.
- B. Do NOT store your Capacitance Meter in extremely hot, humid, or cold environments. Refer to the "Storage Temperature Range" specification on Page 63 of this Manual.
- C. Do NOT apply excessive pressure or stresses to the LCD

POWER SOURCES

You may use either of two power sources for the Capacitance Meter. We recommend an **alkaline** power cell NEDA type #1604 for battery power. You may purchase one of the optional Heathkit Battery Eliminators, Model PS-2350 for 120 VAC operation or Model PS-2450 for 240 VAC operation, if you wish to power the Capacitance Meter without a battery or if you intend to use both.

When you have access to a conventional AC power source, and if you have the proper battery eliminator, merely push the subminiature phone plug into PCB jack J201 and connect the line cord plug to an AC outlet. NOTE: In this Capacitance Meter, the **Battery Eliminator** will **not** charge your battery, which is disconnected from the Capacitance Meter circuitry when the battery eliminator is connected to J201.

NOTE: When the Capacitance Meter is powered by one of the Battery Eliminators, and measuring low capacitance values, you may notice some jitter in the

display readings due to electrical pickup from the power line. If this jitter is excessive, it may be reduced by grounding the negative (–) side of the capacitor being measured.

BATTERY LIFE

Your Capacitance Meter is designed to operate on an inexpensive 9-volt battery (NEDA 1604). If you use an alkaline battery, you can typically expect 4-10 hours of continuous operation (depending on the value of the capacitors being measured. See the chart below:

CAPACITOR VALUE	TYPICAL OPERATING HOURS (Continuous Operation*)
2 nF	10
20 μ F	7
20 mF	4

NOTE: The expected life using a zinc-carbon battery is only about 50-75% of that shown for an alkaline battery.

OPERATING CHARACTERISTICS

The liquid crystal display provides a continuous indication of your Capacitance Meter's operating status: off zero, low battery, and normal operation.

INPUT PROTECTION

When the instrument is "off," the input is protected by a 2.2 Ω , 2-watt resistor placed across the input jacks. With power "on," the input is protected by clamp diodes and a 1/4-ampere fuse.

LOW BATTERY INDICATION

A "LO BAT" indication will appear in the upper left-hand corner of the display when the battery voltage has dropped to approximately 5 volts. Replace the battery as soon as possible after the LO BAT indication appears, or use a Battery Eliminator. However, you may still make "in spec" measurements when the LO BAT first appears. CAUTION: Remove a weak or dead battery promptly to prevent possible damage due to leakage.

*Operating times will be greatly extended during typical operation when sufficient battery recovery time is permitted between operations. The major power consumption takes place in the capacitor charge-discharge circuit. This consumption increases with the increased value of the capacitor being measured.

± 1 COUNT

It is normal for the right-hand digit of the display to alternate one digit above and below a reading on successive conversions.

When you do not have a capacitor installed in the Meter, the first digit of the display may change rapidly in areas of high electrical noise. This is due to the high input impedance and sensitivity of the Meter circuitry.

USE WITH REMOTE CABLE

You may use the remote cable when you need to measure large capacitors or those having screw terminal leads etc. Follow the procedure outlined below when you use the remote cable to measure a capacitor.

1. Carefully insert the printed circuit card connector of the remote cable into the input jacks. NOTE: Be sure you observe the indicated polarity.
2. Connect the two alligator clips with black insulators to the negative (–) lead or terminal of the capacitor (or to the same lead or terminal if the capacitor is not polarized).
3. Connect the two alligator clips with red insulators to the other capacitor lead or terminal.
4. Place the POWER switch in the on position and measure the value of the capacitor (or perform the leakage test as described elsewhere in this section of your Manual). Record this value.

NOTE: If the value of the capacitor is in the pF range, you should determine the value of stray capacitance in the remote cable. Determine this value as follows:

5. Disconnect the remote cable from the capacitor.
6. Connect the two alligator clips with black insulators together.
7. Connect the two alligator clips with red insulators together.
8. Record the open-circuit value as it appears in the display.
9. Subtract the value in step 8 from the value obtained in step 4. The result is the true value of the capacitor you are measuring.

FUSE REPLACEMENT

The Capacitance Meter is protected by the fuse which is installed in the fuse clips on the input circuit board. Replace it only with a 1/4-ampere, 250 V, 8AG regular blow fuse. Using a fuse with a higher current rating may result in damage to the Capacitance Meter.

MEASUREMENTS

This section deals with general, then specific measurement techniques

INTERPRETING THE READING

This instrument will automatically select the correct capacitance range from ten possible ranges and display the correct value for the capacitor being measured. Correct positioning of the decimal point is automatic. The proper LED annunciator (pF, nF, μ F, or mF) also lights automatically to indicate the capacitance unit for the capacitor being measured

CAPACITANCE MEASUREMENTS

1. Select the operating power for the Capacitance Meter (line or battery). Connect the Battery Eliminator to an AC outlet and the Battery Eliminator's plug to the Capacitance Meter if you selected line operation.
2. Depress the POWER pushbutton (SW101) to turn the Meter on. The switch will lock in the on position. Pressing this pushbutton again will turn the Meter off. The initial display reading should be "00.0" with the pF range indicator lit.
3. If the value of the capacitor to be measured is less than 2nF (2000 pF), and the display reading in step 2 is not "00.0," adjust the ZERO control (C103) until you obtain a "00.0" reading with an occasional "00.1" reading displayed. NOTE: This instrument will not display negative values if you should "over-zero" it. It will, however, display a negative (-) sign. This indicates an unacceptable zero setting of this trimmer capacitor. If this happens, adjust the ZERO control until the negative sign disappears and you obtain a reading of "00.0."
4. To measure a capacitor with leads that may be inserted directly into the input jacks of the Capacitance Meter, straighten and clean the leads before you insert them. If the capacitor is an electrolytic (polarized), observe the polarity marking(s) of the capacitor before you insert the leads

The following table indicates the display limits for each of the ten capacitance ranges

CAPACITANCE RANGE	MINIMUM DISPLAY	MAXIMUM DISPLAY
199.9 pF	00.0	199.9
1999 pF	0000	1999
19.99 nF	0.00	19.99
199.9 nF	00.0	199.9
1.999 μ F	000	1.999
19.99 μ F	0.00	19.99
199.9 μ F	00.0	199.9
1999 μ F	0000	1999
19.99 mF	0.00	19.99
199.9 mF	00.0	199.9

READING ACCURACY

Various techniques are used for measuring capacitors. Due to leakage, ESR (Effective Series Resistance), ESL (Effective Series Inductance), dielectric loss, dielectric absorption, voltage coefficient, and temperature coefficient, the value measured for a capacitor may vary widely from time to time and even more from instrument to instrument (method to method). The display error in this type of instrument is produced by the effective series resistance and leakage. Thus, capacitors exhibiting large values of effective series resistance and leakage will produce readings that will vary considerably from readings taken with instruments using other measurement techniques. Such differences in readings should not be considered as errors in either instrument, but rather contributed to the basic nature of capacitors and their parameters.

LEAKAGE MEASUREMENTS

1. Select the operating power for the Capacitance Meter (line or battery). Connect the Battery Eliminator to an AC outlet and the Battery Eliminator's plug to the Capacitance Meter if you selected line operation.
2. Depress the POWER pushbutton (SW101) to turn the Meter on. The switch will lock in the on position. Pressing this pushbutton again will turn the Meter off. The initial display reading should be "00.0" with the pF indicator lit.
3. To determine if excessive leakage exists in a capacitor whose leads may be inserted directly into the input jacks of the Capacitance Meter, straighten and clean the leads before you insert them. If the capacitor is an electrolytic

(polarized), observe the polarity marking(s) of the capacitor before you insert the leads

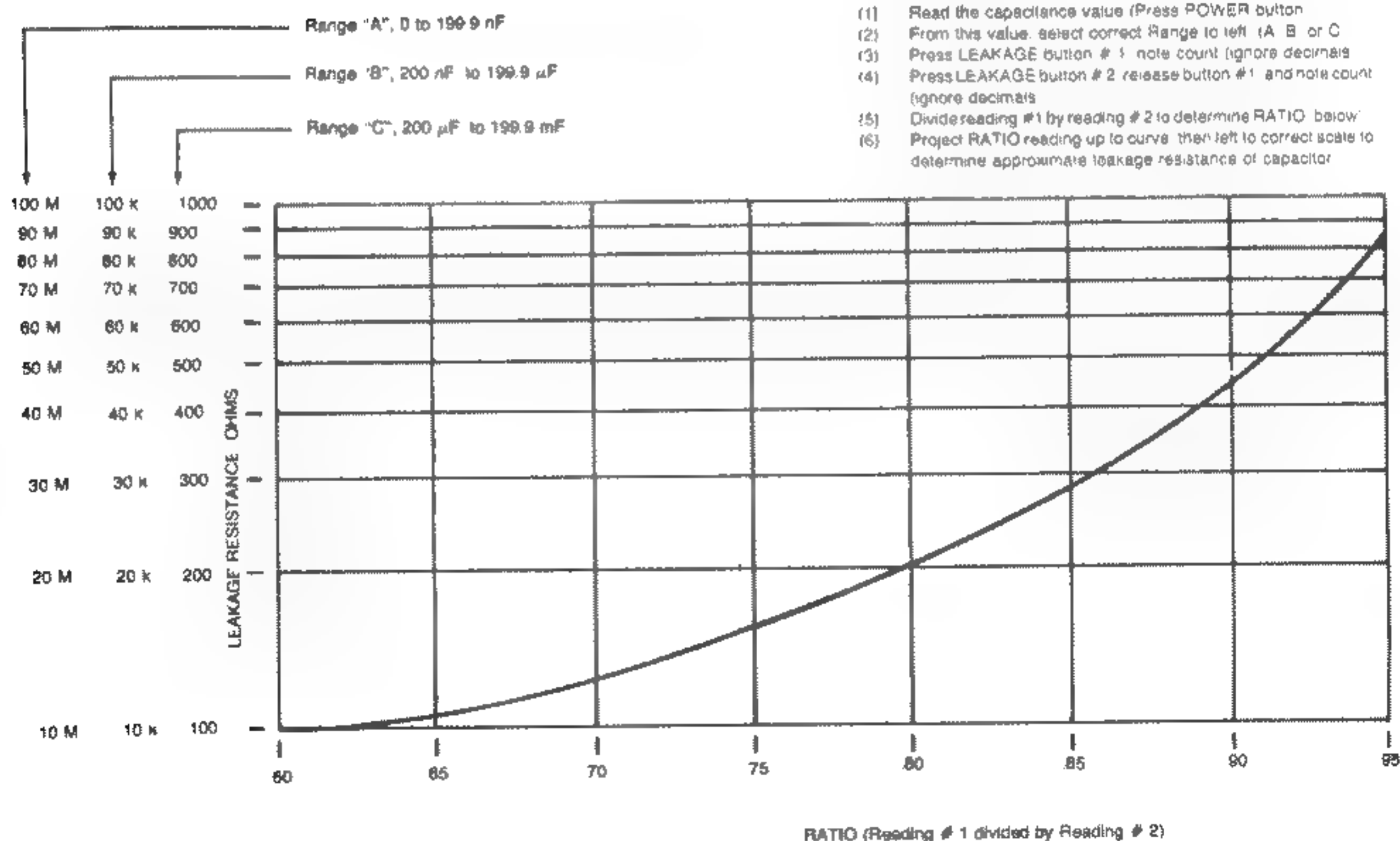
4. Depress and hold LEAKAGE TEST pushbutton #1 and observe the display reading.
5. Depress and hold LEAKAGE TEST pushbutton #2 then release pushbutton #1 and observe the display reading. Then release pushbutton #2.

NOTE: On the higher capacitance ranges, the two readings should be about one-half the value of the capacitance. On all ranges, the readings should be within about 5% of each other in numerical value. A greater difference in the readings indicates excessive leakage. Refer to the nomogram below to determine the approximate leakage value in ohms based on the leakage test readings.

RATIO TEST FOR LEAKAGE RESISTANCE

USING THE NOMOGRAM.

- (1) Read the capacitance value (Press POWER button)
- (2) From this value, select correct Range to left (A, B or C)
- (3) Press LEAKAGE button # 1 note count (ignore decimals)
- (4) Press LEAKAGE button # 2 release button # 1 and note count (ignore decimals)
- (5) Divide reading #1 by reading # 2 to determine RATIO below
- (6) Project RATIO reading up to curve then left to correct scale to determine approximate leakage resistance of capacitor



IN CASE OF DIFFICULTY

This "In Case of Difficulty" section is divided into three parts. The first part, "General Troubleshooting Information," tells you what to look for to eliminate any possible assembly or wiring problems

The second part, "Troubleshooting Precautions," points out the care that is required when you service the Capacitance Meter to prevent damage to the components.

The third part, titled "Troubleshooting Charts," is provided to assist you in servicing the Capacitance Meter if the "General Troubleshooting Information"

fails to clear up the problem, or if difficulties occur after your Capacitance Meter has been in use for some time. The "Troubleshooting Charts" list a number of possible difficulties that could arise along with several possible solutions to those difficulties. Refer to the "Circuit Board X-Ray Views" on Pages 69, 70 and 71 for the physical location of parts on the circuit boards.

NOTE: It is important that you read the entire "General Troubleshooting Information" and "Troubleshooting Precautions", which follow, before you attempt to service your Capacitance Meter.

GENERAL TROUBLESHOOTING INFORMATION

CAUTION: Always be sure the foil side of each circuit board is on an insulated surface; otherwise, the Capacitance Meter can be damaged.

1. Recheck the wiring. It is often helpful to have a friend check your work. Someone who is not familiar with the unit may notice an error that you have consistently overlooked.
2. About 90% of the kits that are returned to the Heath Company for repair do not function properly due to poor connections and soldering. Therefore, you can eliminate many troubles by checking all connections to make sure they are soldered correctly. Reheat the connections, if necessary, but be careful so you do not create any solder bridges.
3. Check to be sure that all transistors and diodes are in their proper locations. Make sure each lead is connected to the proper point. Make sure each diode band is positioned above the band printed on the circuit board or as directed in its step.
4. Check electrolytic capacitors to be sure their positive (+) or negative (-) mark is at the correct position.
5. Check to be sure each IC is properly installed, and that the pins are not bent out or under the IC. Also be sure each IC is installed at the correct location.

6. Check the values of the parts. Be sure the proper part has been installed at each location on the circuit boards. It would be easy, for example, to install a 4700 Ω (yel-viol-red) resistor where a 47 k Ω (yel-viol-org) resistor should have been installed
7. Check for bits of solder, wire ends, or other foreign matter which may be lodged in the components on the circuit boards
8. Check very carefully to be sure there are no solder bridges between different circuit board foils. If you are not sure that a solder bridge exists, compare the circuit board foil with the "Circuit Board X-Ray Views" on Pages 69, 70 and 71 in this Manual. Remove any solder bridges by holding a clean, hot soldering iron tip between the two points that are bridged until the excess solder flows down onto the tip

If you still cannot locate and correct the trouble after you have completed the checks listed above, and if a voltmeter is available, check the voltages in the Capacitance Meter against the Schematic. A review of the "Circuit Description" and the Schematic may also help you locate any difficulties in the kit. You may also find the "Operational Logic Flow Chart" (fold-in) useful. In an extreme case where you are unable to resolve a difficulty, refer to the "Customer Service" information inside the rear cover of this Manual. Your Warranty is located inside the front cover.

TROUBLESHOOTING PRECAUTIONS

- Be sure you do not short any adjacent terminals or foils when you make tests or voltage measurements. If a probe or test lead slips, for example, and shorts together two adjacent connections, it is very likely to cause damage to one or more IC's, transistors, or diodes.
- Be especially careful when you test any circuit that contains an IC or a transistor. Although these components have almost unlimited life when used properly, they are much more vulnerable to damage from excessive voltage or current than many other parts

- In several areas of each circuit board the foil patterns are quite narrow. When you unsolder a part to check or replace it, avoid excessive heat while you remove the part. A suction type desoldering tool will make removal considerably easier. You may also use the desoldering braid supplied with this kit to remove the solder

Once the Capacitance Meter has operated properly initially, the two input test jacks are probably the only items that will cause the Meter to malfunction. You may clean these by carefully sliding **fine** sand paper or a **thin** fingernail emery board between the pair of contacts making up each test jack. CAUTION: Be careful so you do not spring the contacts apart.

If the troubleshooting extends beyond the chart that follows, you may need an oscilloscope. Lock the Capacitance Meter on the "0" range by connecting a wire from the hot side of resistor R206 (pin 15 of IC U205) to +V_{DD} (pin 16 of IC U205). This holds the range counter reset at "step 0" and thus inhibits the auto-ranging function. You can then observe repeated waveforms and logic voltages on the oscilloscope. You can prevent the Capacitance Meter from making repeated auto-ranging cycles (thus allowing it to make continuous measurements on the same range) by connecting a wire across resistor R206.

CIRCUIT BOARD CLEANING

Use the following "last resort" procedure to clean a contaminated circuit board

1. Remove the bezel, the liquid crystal display, and the LCD holder from the display circuit board
2. Use demineralized water and a soft brush to clean the entire circuit boards and the pushbutton switch assembly. CAUTION: Avoid getting excessive amount of water in the switches
3. Bake at 150°F (65°C) for 5 hours. CAUTION: Allow the circuit boards time to cool before you reassemble the instrument

TROUBLESHOOTING CHARTS

The following charts list the condition and the possible causes of several malfunctions. If a particular part is mentioned as a possible cause, check that part to see if it was correctly installed. Also check it and the parts connected to it for poor connections. It is also possible, on rare occasions, for a part to be faulty and require replacement.

CONDITION	POSSIBLE CAUSE
1 No part of the display or none of the range indicators lights	A. Dead battery B. J201 C. SW101 D. LCD301
2 "LO BAT" is displayed	A. Low battery voltage
3 Display reads only "00 0" even after sufficient time is allowed.	A. Input test jacks sprung open B. Over-range condition (greater than 199.9 mF)
4 Display shows random numbers, multiple or faded segments.	A. Input test jacks sprung open B. Low battery voltage C. Fuse F101 open
5 Erratic readings.	A. Dirty leads on test capacitor B. Faulty test capacitor C. Electrical noise pickup
6 Display reading drifts steadily in one direction.	A. Faulty test capacitor B. Very low battery voltage

CALIBRATION PROBLEMS

PROBLEM	POSSIBLE CAUSE
1 When calibrating a lower range, Meter reads on next high range	A. Calibration resistor on range being calibrated is set too low, rotate counterclockwise until operation occurs on correct range
2 Cannot bring into correct calibration reading.	A. Zero not set properly (on lower ranges), reset zero
3 Cannot zero Meter with no capacitor installed, reads high	A. Circuit board contamination. (See "Circuit Board Cleaning") B. Incorrect stray capacitance due to faulty component C. Deformed input contacts D. Check for faulty part or improper operation. See note at bottom of page
4 Cannot zero Meter with no capacitor installed, reads 00 0	A. Incorrect stray capacitance due to faulty component B. Circuit board contamination C. Input jack sections not in contact with each other D. Check for defective parts or improper operation. (See note at bottom of page)

NOTE: If you cannot zero the Meter with no capacitor installed, and the above checks fail to clear up the problem, contact Heath Company Technical Correspondence.

SPECIFICATIONS

NOTE: The accuracy of the IT-2250 Capacitance Meter depends on whether you calibrate it using the Heath supplied standards or laboratory standards. Specifications are listed for both methods of calibration. Accuracy specifications apply for a 67°F to 77°F (19°C to 25°C) temperature range

Ranges	199.9 pF, 1999 pF, 19.99 nF, 199.9 nF, 1.999 μ F, 19.99 μ F, 199.9 μ F, 1999 μ F, 19 99 mF, 199.9 mF
Accuracy	<p>Heath supplied standards*</p> <p>199.9 pF, 1999 pF, 19.99 nF, 199.9 nF ranges: \pm(.5% of reading + 1 count + .5 pF).</p> <p>1.999 μF, through 199.9 mF ranges: \pm(5% of reading + 1 count).</p> <p>Laboratory standards</p> <p>199.9 pF, 1999 pF, 19.99 nF, 199.9 nF ranges: \pm(.2% of reading + 1 count + .5 pF).</p> <p>1.999 μF, through 199.9 mF ranges: \pm(5% of reading + 1 count).</p>

*Calibration accuracy stated for Heath supplied standards applies when the standards and the Meter are kept within a 67° to 77°F temperature range

Conversion and Display Rate	Values up to 1999 μ F: less than 1.5 seconds. Values up to 199.9 mF: less than 10 seconds.
Operating Temperature Range	32° to 104°F (0° to 40°C).
Storage Temperature Range	-4° to 140°F (-20° to 60°C).
Power Requirements	9-volt battery (NEDA 1604) or Heath PS-2350 or PS-2450 Battery Eliminator.
Battery Indicator	Displays "LO BAT" when battery voltage is down to approximately 5 volts.
Display	3-1/2 digit (1999 maximum count) liquid crystal.
Testing Voltage	2.00 VDC maximum; typically varying from .6 to 1.4 VDC.
Dimensions	2" (H) \times 3-1/4" (W) \times 7-1/2" (L) (5.1 \times 8.3 \times 19.1 cm).
Weight	16 oz. with battery. (450 g).

The Heath Company reserves the right to discontinue products and to change specifications at any time without incurring any obligation to incorporate new features in products previously sold.

THEORY OF OPERATION

Refer to the Block Diagram (Illustration Booklet, Page 8) as you read the following material.

The Capacitance Meter determines the value of a capacitor by measuring the time it takes to charge the capacitor from one fixed reference voltage to a second reference voltage; then to discharge the capacitor back to the first reference voltage. That is, it measures the time required for one charge/discharge cycle. The time is determined by counting the number of crystal controlled clock pulses fed into the display counters during this charge/discharge cycle. This count reads directly in the value units of the capacitor.

The unknown capacitor (C_x) is charged from a fixed, internal 2-volt reference source through a solid-state switch and a fixed calibration resistor (R^*). The increasing voltage on the unknown capacitor is monitored by one input of comparator U101. The other comparator input monitors a voltage developed from the reference supply across resistors R104 and R106. Resistor R105 is a hysteresis resistor that shunts R104 during the charge cycle and then shunts R106 during the discharge cycle; thus causing the reference voltage on the comparator (-) input to change from approximately 1.4 volts (charge cycle) to .6 volt (discharge cycle) as controlled by the solid-state hysteresis switch.

When the charging voltage on the capacitor reaches the 1.4-volt level on the comparator (-) input, the comparator output suddenly changes state. This switches both the solid-state charge/discharge and the hysteresis switches, causing the discharge cycle to start. When the capacitor voltage drops to .6 volt,

the comparator output again changes state, and another charge cycle begins. The output of the comparator operates the solid-state switches and other circuitry after passing through the wave-shaping and inverter circuits and resistor select logic.

The rectangular waveform output of the comparator is also used to control a clock gate to pass the selected frequency to the display counters when required. This gate normally passes the clock signal during the entire charge/discharge cycle, except for a very small time that is set aside for loading the count into the display and resetting counter and logic circuits. The clock gate is also inhibited on the pF ranges for a time which is determined by the zero-compensation flip-flop circuit. This circuit generates the inhibit pulses equal in time to the equivalent stray capacitance in the circuits and/or test leads. (NOTE: This compensation time is actually much longer than the time required for loading the data count and resetting the circuits; thus no time is "lost" during the operation of the logic circuits as they update the display.) The length of the pulse is fixed by the output from one of the clock frequency dividers. Fine adjustment of the "zero" is accomplished by an adjustable shunt capacitor which is varied to adjust the total stray capacitance so it is exactly equal to the zero-compensation flip-flop time period.

The output of the display counters is in BCD (Binary Coded Decimal) form and is loaded into the display decoders with each update (load) command. The data is then decoded and operates the LCD (liquid crystal display) with decoding and driving circuits.

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If the capacitance is large enough to cause overflow of the display counters (a count in excess of 1999), the carry signal advances the range counter to the next range and another measurement cycle begins.

The 1-of-10 decoding (for ten ranges) of the range counter is used for the following.

1. To control the selection of the charge/discharge resistors (three different resistor networks are used for the ten ranges). Refer to the "Appendix" on Page 77.
2. To control the selection of the three decimal points in the display
3. To control the selection of the clock frequency.
4. To control the range indicator select circuits.
5. To enable the zero circuit on the first four ranges.

The 3.58 MHz clock frequency is generated by a crystal-controlled oscillator for good frequency stability. This frequency is then digitally divided by the clock frequency dividers to provide selectable clock frequencies of 358 kHz, 35.8 kHz, 3.58 kHz, and 358 Hz. The selected clock frequency for each range is decoded by the clock frequency select circuits.

As previously stated, the unknown capacitor is charged/discharged between two reference voltages (rather than being completely discharged). Thus some bias voltage always appears on the capacitor after the first cycle of operation. During the first cycle, however, data must not be taken because of the extra time required to charge the capacitor up to the lower reference level. The second cycle detect circuit detects the first cycle and inhibits loading of data into the display during this first cycle. Also, if a range change has occurred during any cycle, data must not be displayed for that cycle. This condition is detected by the range-change detect circuits. The load data circuit also reduces the rate of data update on the low capacitance ranges to minimize display jitter.

Immediately after the generation of each load pulse in the load pulse generator, a reset pulse is generated to reset all counter and logic circuits

Power for the system is supplied by the internal 9-volt battery, or by an optional battery eliminator, which is regulated to 5 volts DC by the 5-volt power regulator. Each time the Meter is "turned on," the power-up reset circuit generates a reset pulse for all the related circuits. The low battery detector detects whenever the battery voltage has dropped to approximately 5 volts and signals an indicator in the display (NOTE: Operation is still valid when this indicator first comes on, but the battery should be replaced as soon as possible.)

The ratiometric charge/discharge operation of the system is in accordance with the equation $t/2 = RC \ln 2$ where:

$t/2$ = one charge or one discharge or 1/2 measurement cycle.

R = the charge/discharge resistor value in ohms.

C = the unknown capacitance in farads.

\ln = the natural logarithm (or Napier logarithm).

Both the charge and discharge times of each measurement cycle are equal in time, if the unknown capacitor has no shunt resistance (leakage). Any leakage resistance will both increase the charge time and decrease the discharge time. In the leakage test mode of operation, the time period for first the charge cycle (pushbutton #1) and then the discharge cycle (pushbutton #2) is displayed. A large difference in the displayed numbers indicates a leaky capacitor.

Also due to the ratiometric measurement technique, any variation in the charge/discharge reference voltage does not affect the readings, since this same voltage is used for comparator reference, thus making the system immune to small variations in the power supply voltage.

CIRCUIT DESCRIPTION

Refer to the Block Diagram (Illustration Booklet, Page 8) and the Schematic (fold-in) while you read this "Circuit Description." The part numbers are arranged in the following groups to help you locate specific parts on the Schematic and the circuit boards.

- 101-199 Parts on the input circuit board.
- 201-299 Parts on the main circuit board.
- 301-399 Parts on the display circuit board.

The Meter measures the unknown capacitance by measuring the time required to change the capacitor from some fixed reference voltage (bias voltage) up to another fixed reference voltage and then to discharge the capacitor back to the original reference voltage. The time required for this charge/discharge cycle is directly and linearly proportional to the value of the capacitance.

The capacitor is connected to the system by a 4-terminal or Kelvin connector (one pair of contacts, or circuits, to the capacitor are the current-carrying ones, and the remaining pair of contacts are the capacitor voltage-sensing circuits). This prevents any voltage drop across the current circuits from producing an error in determining the actual capacitor voltage. A reference voltage of approximately 2 volts DC is provided by diode string D104 through D106, operational amplifier U102, and transistor Q116.

Over the range of capacitance measurement possible with the Meter, the unknown capacitor is charged and then discharged through any one of three resistor networks with its respective charge/discharge switching transistor pair. At the beginning of each measurement, the Meter tries to make the first measurement on the smallest capacitance range (199.9 pF). Q107 first charges the capacitor to the upper reference voltage through R128 and R129 (the calibration resistor), and then discharges the capacitor through the same resistors and Q108.

The voltage across the capacitor is sensed at the + input to comparator U101 and compared to the voltage on the - input, which is derived from a voltage divider consisting of R104 and R106 across the 2-volt reference supply. During the charge portion of a measurement cycle, Q101 effectively connects R105 in parallel with R104, thus setting the voltage on the comparator - input at a value slightly higher than one-half the reference voltage (about 1.4 volts). During the discharge portion of a cycle, Q102 connects R105 in parallel with R106, setting the voltage to less than one-half the reference voltage (about 0.6 volt). The net result is a comparator with hysteresis; that is, the output of the comparator changes to a saturated + output when the capacitor voltage (during the charge cycle) crosses a value slightly higher than one-half the reference voltage. Correspondingly, during the discharge cycle, the comparator output saturates low when the discharging capacitor voltage reaches a value slightly below one-half the reference voltage.

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Thus the output of the comparator is a symmetrical waveform corresponding to the charge/discharge voltage on the capacitor. The capacitor voltage "oscillates" an equal voltage above and below one-half the reference voltage.

During each measurement cycle, a clock frequency is gated to a display counter to present a count proportional to the charge/discharge time and thus proportional to the capacitance.

If the capacitance being measured is so large that an overflow of the digital data counters occurs (count greater than 1999), then several more measurement attempts are made, each with a lower clock frequency. If overrange still occurs after all clock frequencies have been tried, the next charge/discharge resistor network (R122 and R123) is tried with its respective switches (Q105 and Q106). At the largest capacitance ranges, the final resistor network (R117, R115, and R116) is employed with switches Q103 and Q104.

The comparator output waveform is wave-shaped to provide a fast rise and fall time by Q109 and Q110. Note that the output of Q109 is inverted while the output of Q110 is in phase with the comparator output. This waveform drives the enable logic for the charge/discharge switches. The logic for selecting the correct switch pair consists of three gate sections each of U103 and U104. Whichever gate pair is selected by the control system logic respectively turns on and off its related transistor switches and insures that in the disabled state both of its related switches are off.

Additional logic circuits on the input circuit board include a dual clock gate flip-flop (U105). At the end of each measurement cycle (end of a capacitor discharge cycle), the low-going output from Q109 sets the clock gate flip-flop (U105 A & D) so the output from pin 11 is low, thus closing the clock gate (U210 B) through D107, SW103A and SW102A. After the data has been loaded, this flip-flop is reset to open the clock gate.

When measuring small capacitances, some form of zero or compensation to correct for stray circuit

capacitance is required. This is accomplished on the pF ranges (only) by the zero-compensation flip-flop (U105 B & C). At the end of each measurement cycle this flip-flop is set by the reset pulse so that pin 10 of U105C is low, holding off the clock gate (U210 B). Note that in any range other than the A range, pin 12 of U103 D and pin 1 of U104 A are low (disabled) and the flip-flop is held reset through R134 so that the zero compensation flip-flop cannot function to block clock signals.

At a time approximately corresponding to the stray capacitance, a digital output from the clock frequency divider (U205 pin 6 via Q115) resets the flip-flop. This allows the clock pulses to pass.

Final adjustment of the zero is made by C103 and C104, respectively fine and coarse zero capacitance adjustments, which bring the net circuit board stray capacitance exactly corresponding to the time at which output from the frequency divider (U205) occurs.

If the system has been over-compensated (over-zeroed), the zero-compensation flip-flop (U105 B & C) is never reset by an output from U205 before the end of a measurement cycle. This condition is detected by pin 1 of U210 A, in turn, feeding data to the latch (U214) and finally, to the display minus sign.

The charge/discharge time is measured by counting the clock frequency cycles in the display counters. The clock frequencies are generated from a crystal-controlled base frequency of 3.58 MHz, which is in turn divided successively by 10 (U203, U204A, U204B, and U205 A) to produce a selection of clock frequencies of 3.58 MHz, 358 kHz, 35.8 kHz, 3.58 kHz, and 358 Hz. The selection of the correct clock frequency is implemented by a range counter (U205 B) and its 1-of-10 decoder (U206).

At the beginning of each measurement, U206 is at its 0 position (00.0 pF). Each time the range is changed, the output of U206 advances to the next position. The output from U206 is then decoded to select: (1) the correct range decoding resistor (U207 A & B, U208 C, and U209A), (2) the correct range indicator LED

(U211 A, U211 C, U209 D, U207 B, and U208 C), (3) the correct decimal point (U222 A & B), and (4) the correct clock frequency (U208 A, B, & D, U210 D, U211B, U213 A & B, U212 A,B,C.&D, and U210 B — the clock enable gate). The gated, selected clock frequency (pin 4, U210 B) is fed to the decade counter, U220, and the cascaded remaining counters on the Display Board (U304). The output of these counters is loaded and decoded for the 7-segment LCD display by U301, U302, and U303.

Information for the LED range indicators and the decimal points is latched by U214 and U215, respectively. U216 A,B,C, and D perform the proper phase inversion for driving the respective decimal points and the 1 K digit of the display. U219 A is a Jk flip-flop used to operate the 1 for the thousands display (1 K) upon overflow from the last display counters, U304 B. U209 C provides correct phasing for driving the "LO BAT" display indicator.

During measurement, logic must provide information as to when a successful data measurement has been made, and then to update the display. Also, measurement must not be made during the first charge cycle after initial power turn-on. This later function is performed by the second cycle flip-flop, U217 A & B, whose output opens load-pulse pass gate U221 C only after a second cycle has occurred. Each time a range change has been made (due to counter overflow output from U219A to U210 C to U205), the range-changed flip-flop, U219 B, is set to prohibit passage of the load pulse by blocking gate U221 C, in turn blocking gate U221 B. Without this inhibit, the load pulse (generated by U218 A, as triggered from the change of state on the comparator output) will pass to U221 A. The load pulse may again be stopped at U221 A if a recent load has been passed, due to the blocking ac-

tion of a one-shot timer, (U221 D) — which prevents excessive data update on the low capacitance ranges and the resulting display jitter.

Once the load pulse has passed through all the inhibit gates and D205, it loads data into the two latches (U214 and U215) and to the display drivers (U301, U302, and U303). This load pulse also resets the range counter (U205 B) via U202 D.

The load pulse generated by U218 A also triggers generation of a reset pulse by U218 B to reset all logic and counters once a measurement cycle has been completed.

U202 E and F generates an initial "power up" reset pulse to reset all counters and logic, and to load the display with all zeroes. U201 provides a regulated 5 volts DC for all circuitry. Q201 and Q202 detect a low battery condition.

The liquid crystal display requires that its segments be operated from reversing polarity voltage to prevent electroplating action in the display. This is done by operating the backplane (common element) of the display with the square wave output from the comparator (U101). The individual segments are also operated from this same signal, but the waveform is inverted (when compared to the backplane signal) for an "on" segment (out of phase), and in phase with the backplane when the segment is off. The correct phase relationship is determined by U216 A,B,C, and D and U209 B & C, as well as display drivers U301, U302, and U303.

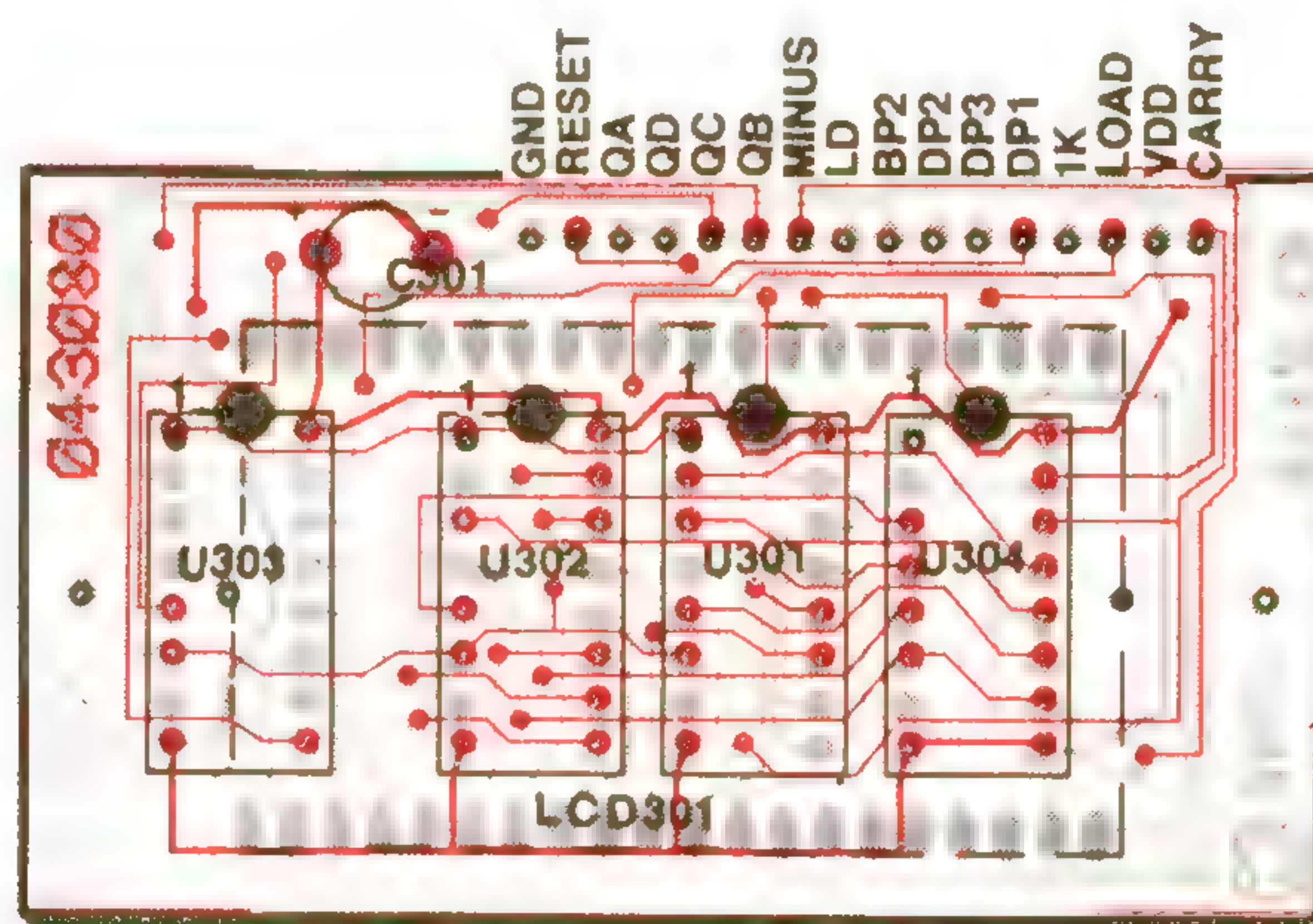
All logic circuitry is CMOS except U203 and U220. These are Schottky devices which are required for their high frequency inputs as well as low power consumption.

CIRCUIT BOARD X-RAY VIEWS

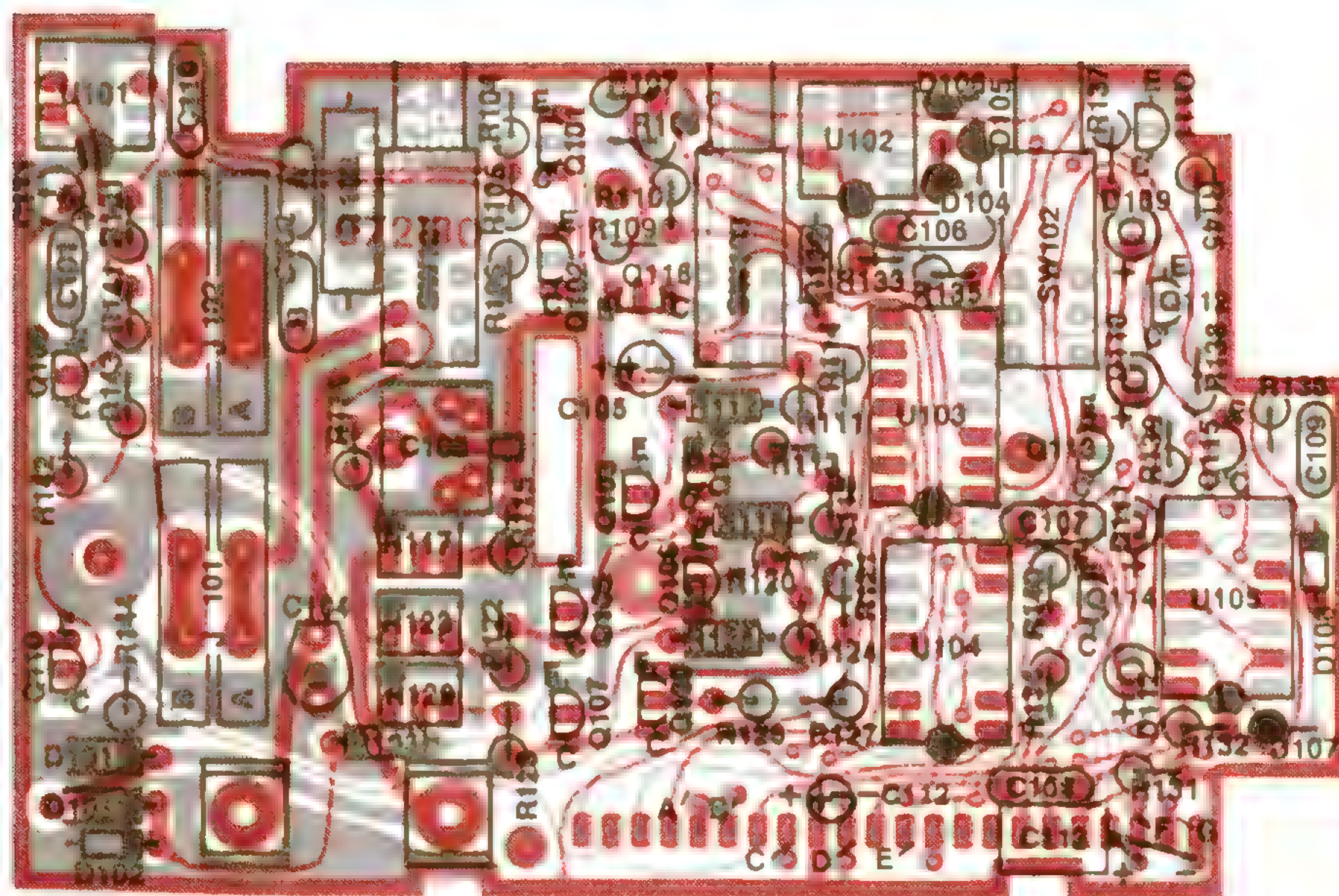
NOTE: To find the PART NUMBER of a component for the purpose of ordering a replacement part:

- A. Find the circuit component number (R5, C3, etc.) on the X-Ray View.
- B. Locate this same number in the "Circuit Component Number" column of the correct "Parts List."

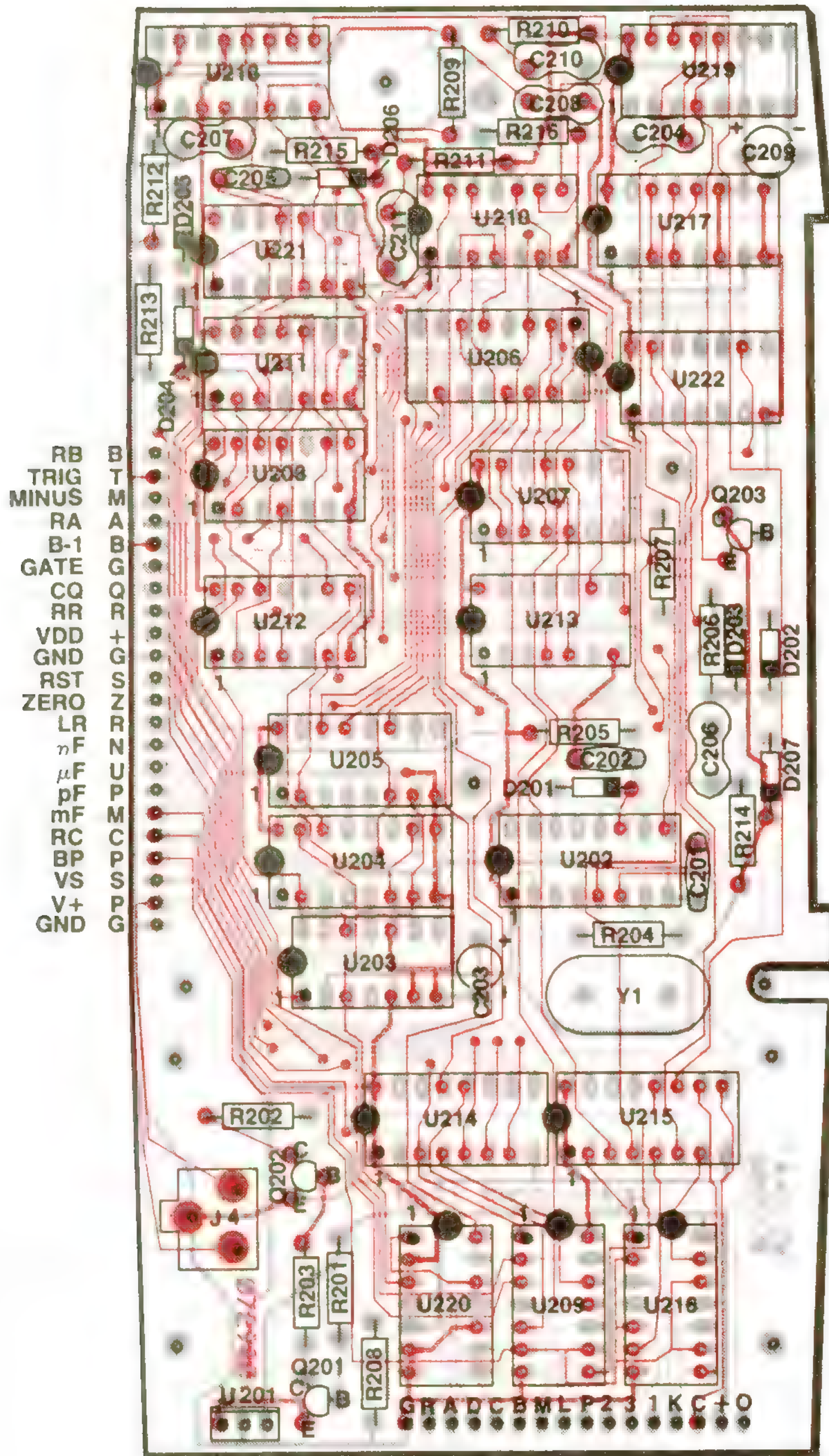
- C. Adjacent to the circuit component number, you will find the PART NUMBER and DESCRIPTION which must be supplied when you order a replacement part.



DISPLAY CIRCUIT BOARD
(Viewed from the component side)



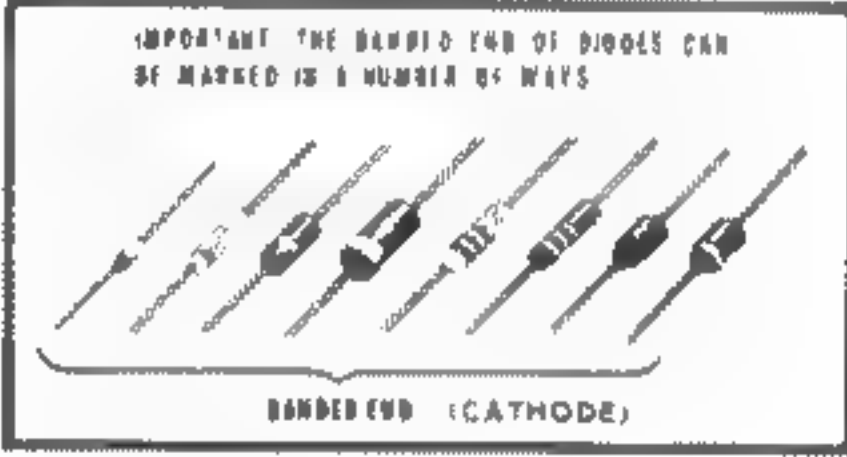
INPUT CIRCUIT BOARD
(Viewed from the component side)



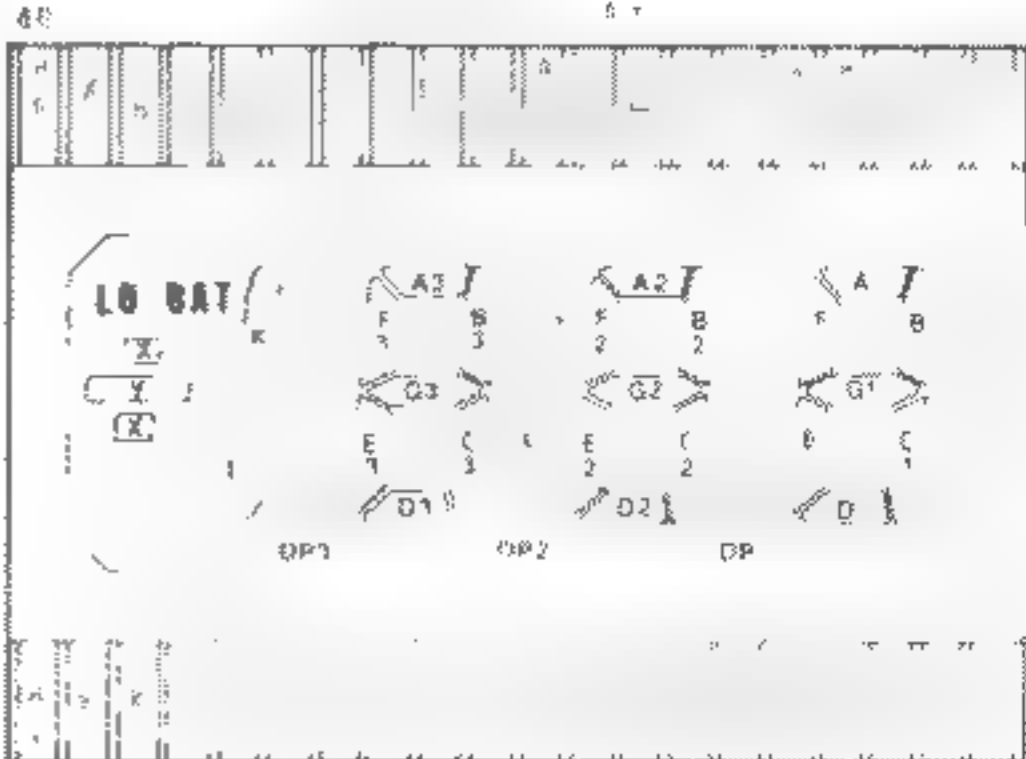
MAIN CIRCUIT BOARD
(Viewed from the component side)

SEMICONDUCTOR IDENTIFICATION CHARTS


DIODES

CIRCUIT COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
D104 D105 D106 D107 D108 D201 D202, D203, D204, D205 D206 D207	56-56	1N4149	
D101 D103	56-93	FD333	
D102	56-619	1N4733A	

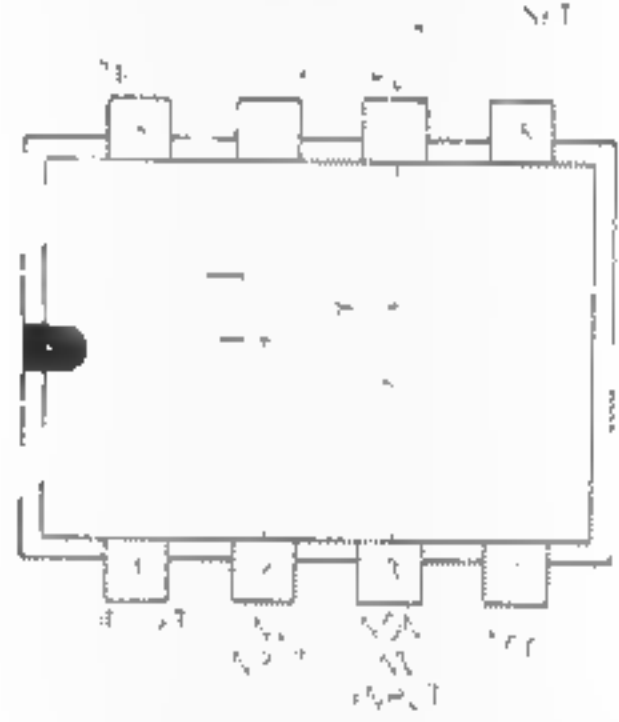
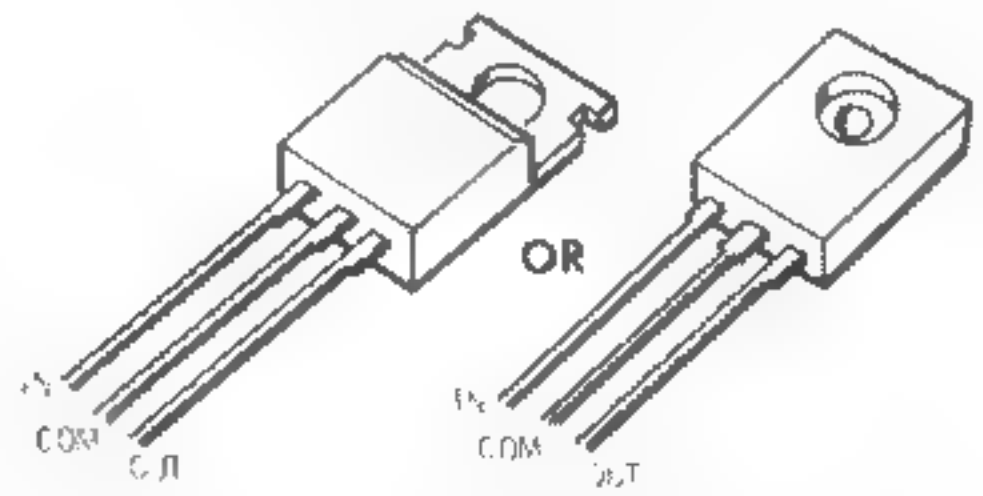
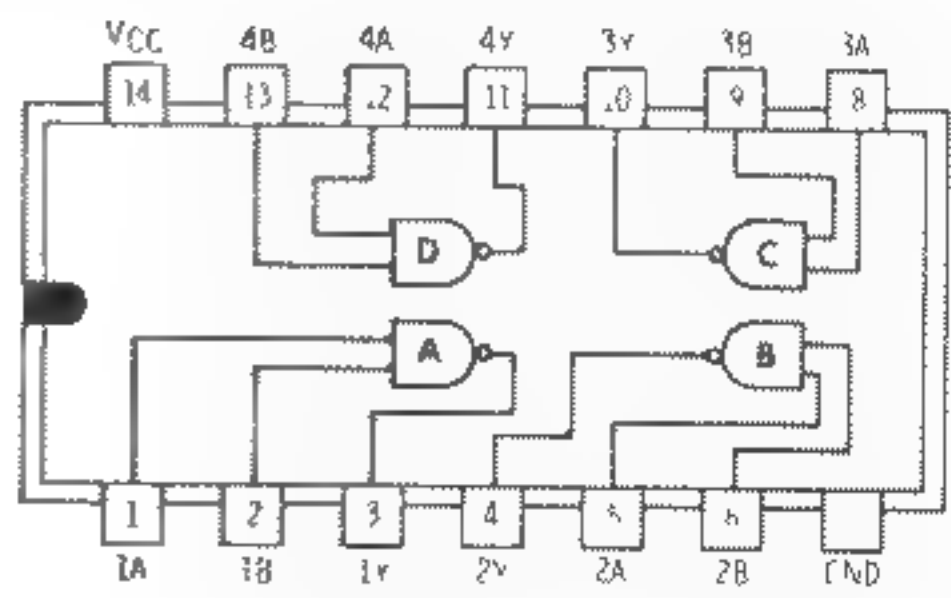
DISPLAY

CIRCUIT COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
LCD301	411 843	AND FE0203 or BECKMAN 739-02050 or HAMLIN 3933-363-159	

TRANSISTORS

CIRCUIT COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
Q102 Q104 Q106 Q108 Q109 Q111, Q112 Q113, Q114 Q115 Q116, Q202 Q203	417-864	MPSA05	
Q101, Q103, Q105 Q107, Q110, Q201	417-865	MPSA55	

INTEGRATED CIRCUITS (IC's)

CIRCUIT COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
U101	442-715	CA3130E	
U102	442-22	5741	
U201	442-716	LM330T	
U103 U105	443-603	4011	

INTEGRATED CIRCUITS (Cont'd.)

CIRCUIT COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
U217, U219	443-606	4027	
U202	443-701	4049	
U208, U211	443-706	4071	
U206	443-713	4028	

INTEGRATED CIRCUITS (Cont'd.)

CIRCUIT COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
U204 U205 U304	443-737	4518	
U104, U210 U212 U221	443-751	4061	
U209, U216	443-784	4070	
U203 U220	443-813	74LS90	

INTEGRATED CIRCUITS (Cont'd.)

CIRCUIT COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
U214 U215	443-836	4174 or 340174	
U218	443-916	4538	
U301, U302, U303	443-931	4543	
U207, U213 U222	443-950	4072	

APPENDIX

AUTO-RANGING TABLE

STEP NUMBER	RANGE	CLOCK FREQ.	CAPACITANCE RANGE	RANGE INDICATOR	DECIMAL POINT	REMARKS
0	A	3 58 MHz	199 9	pF	00 0	ONLY RANGE USING 3 58 MHz
1		358 kHz	1999	pF	NONE	
2		35 8 kHz	19 99	nF	0 00	
3		3 58 kHz	199 9	nF	00 0	
4	B	358 kHz	1 999	μ F	000	
5		35 8 kHz	19 99	μ F	0 00	
6		3 58 kHz	199 9	μ F	00 0	
7	C	35 8 kHz	1999	μ F	NONE	
8		3 58 kHz	19 99	mF	00	
9		358 Hz	199 9	mF	00 0	ONLY RANGE USING 358 Hz

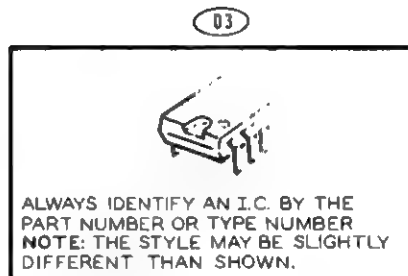
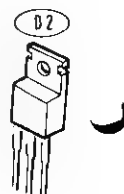
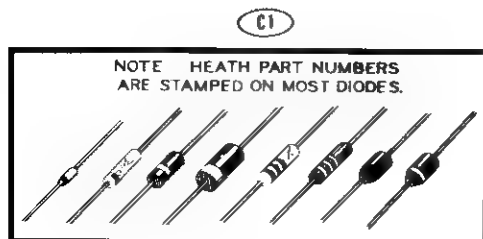
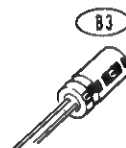
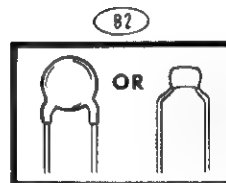
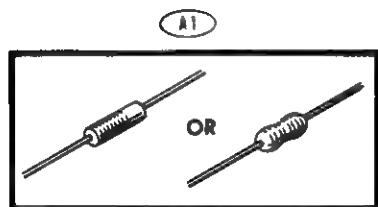


HEATH COMPANY • BENTON HARBOR, MICHIGAN
THE WORLD'S FINEST ELECTRONIC EQUIPMENT IN KIT FORM

LITHO IN U.S.A.

ILLUSTRATION

MAIN CIRCUIT BOARD



ON BOOKLET

Part of 595-2450-02

ARD PARTS PICTORIAL

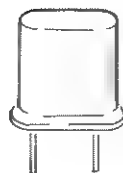
E1



E2



E3

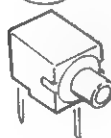


E4



ALWAYS IDENTIFY AN IC SOCKET
BY COUNTING ITS PINS.
NOTE: THE STYLE MAY BE SLIGHTLY
DIFFERENT THAN SHOWN.

E5



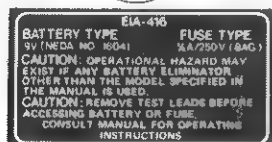
E6



F2

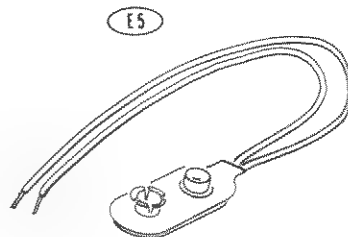
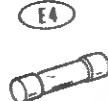
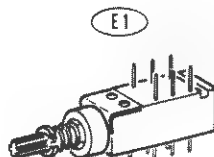
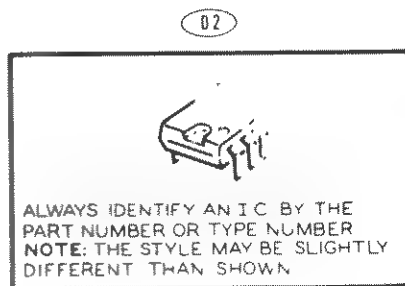
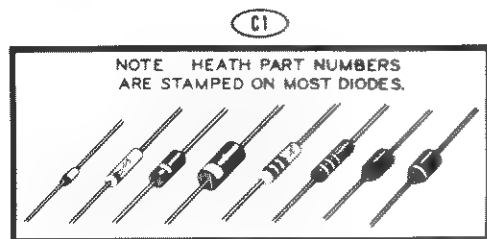
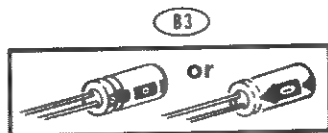
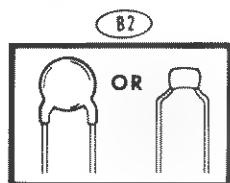
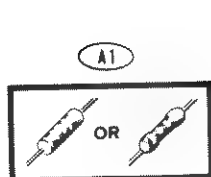


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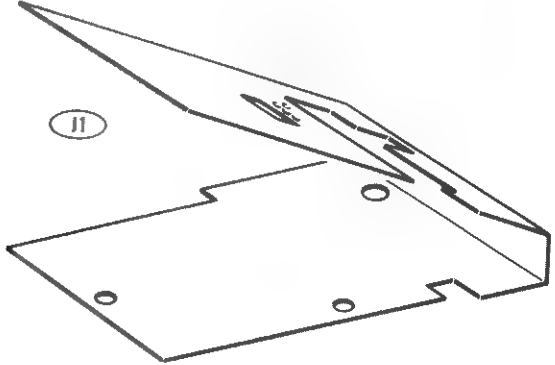
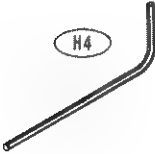
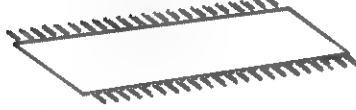
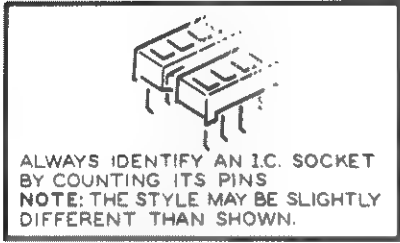


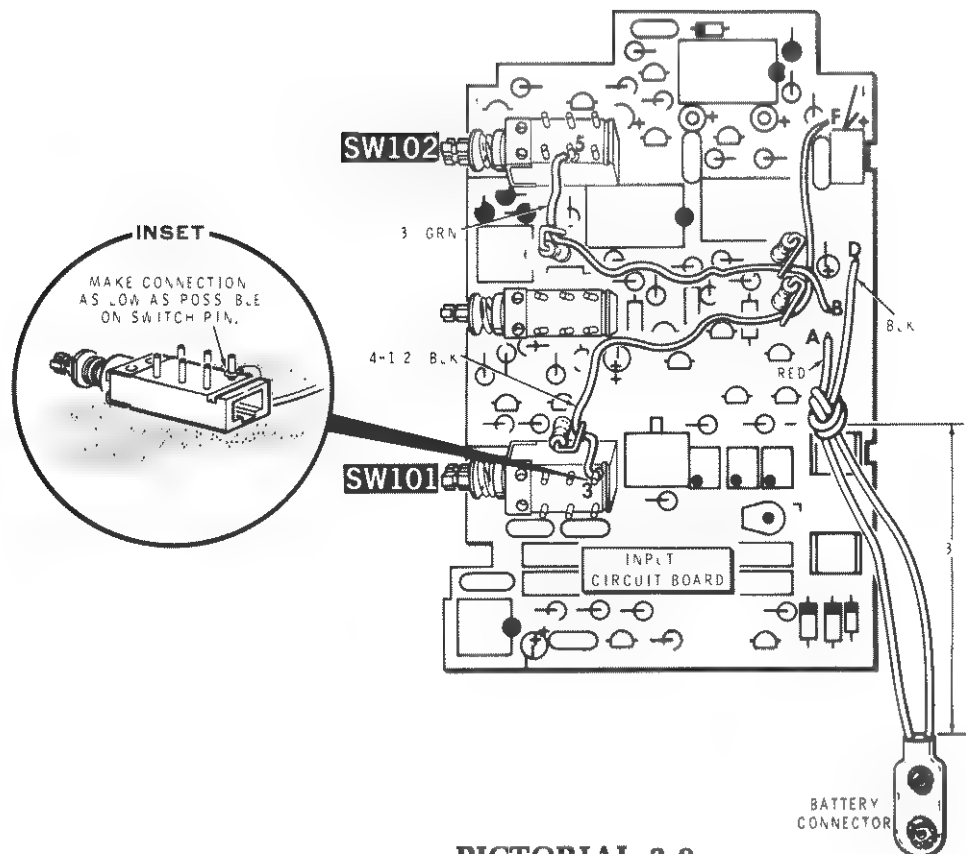
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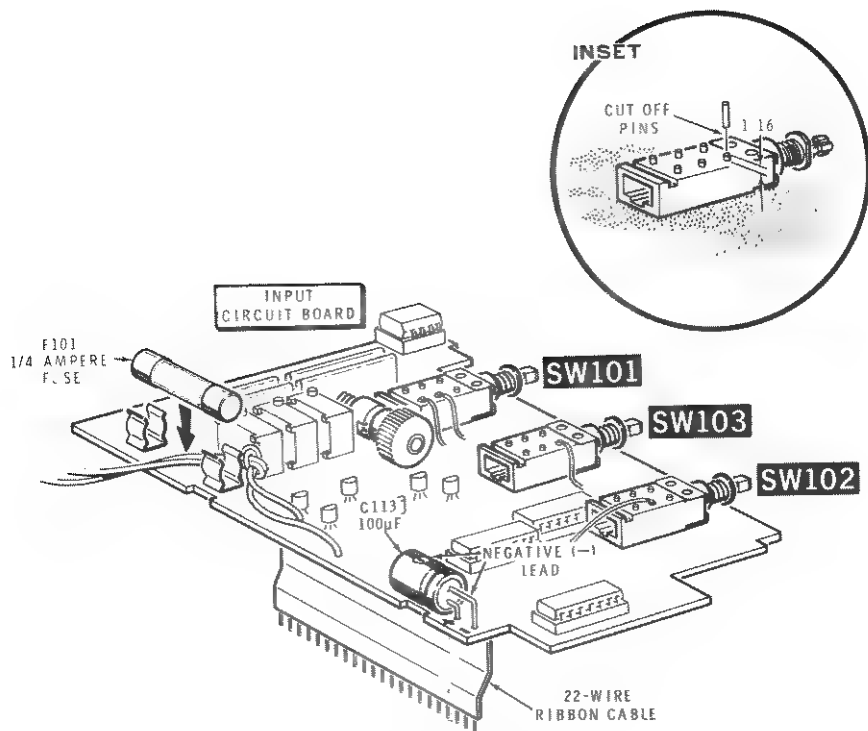


RD PARTS PICTORIAL

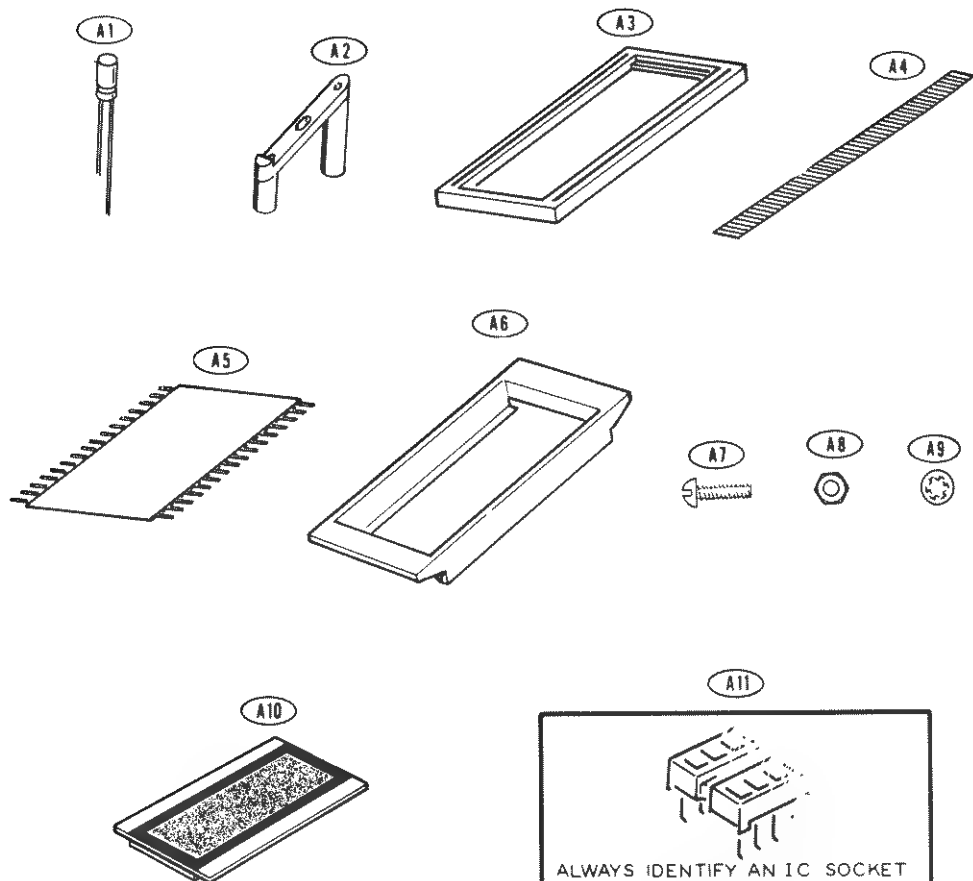




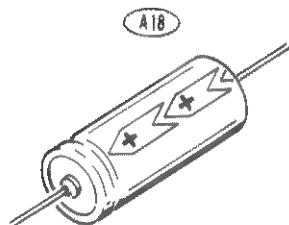
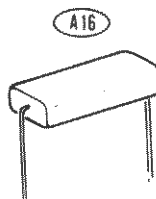
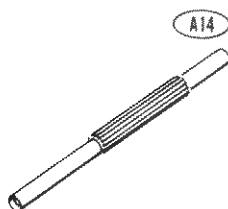
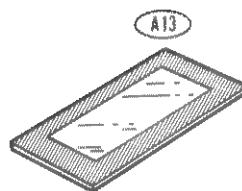
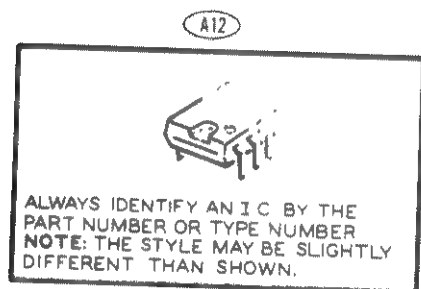
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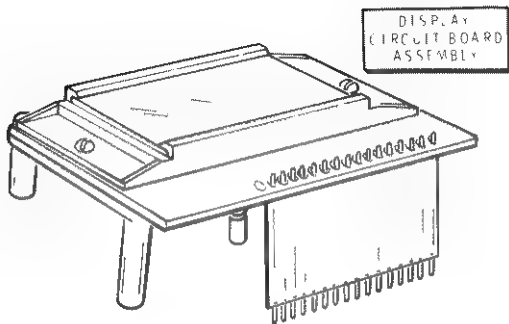


PICTORIAL 2-11

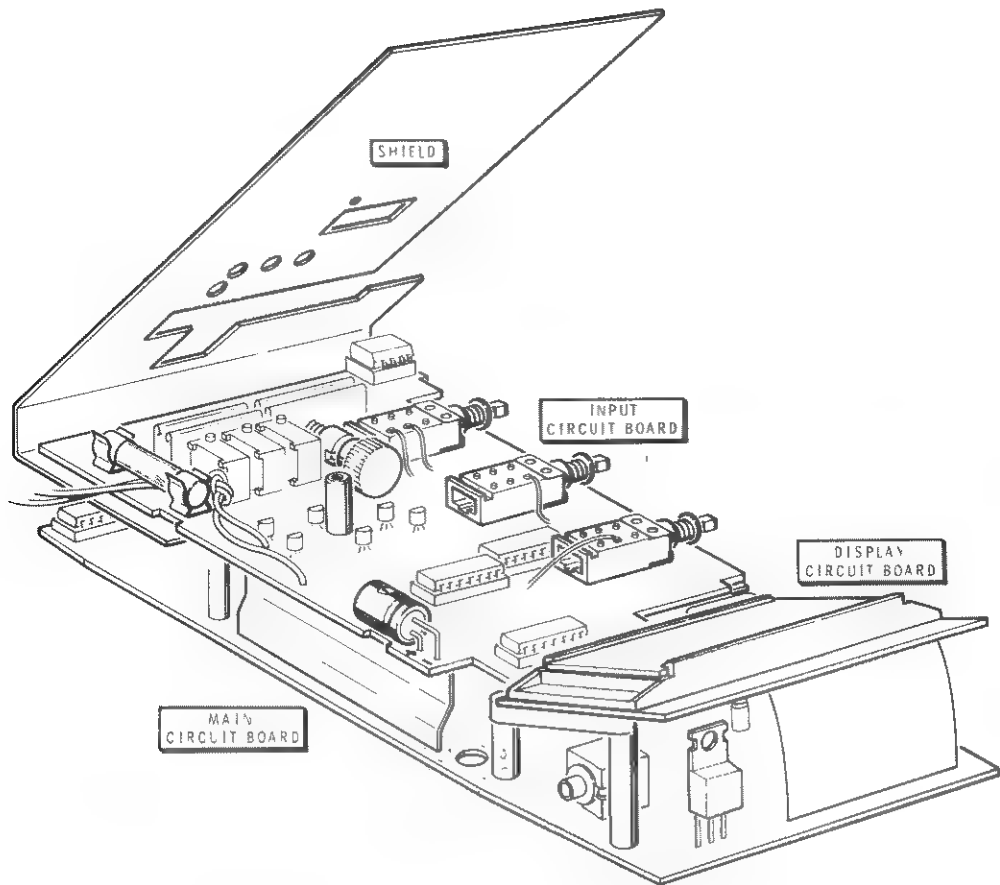


ALWAYS IDENTIFY AN IC SOCKET
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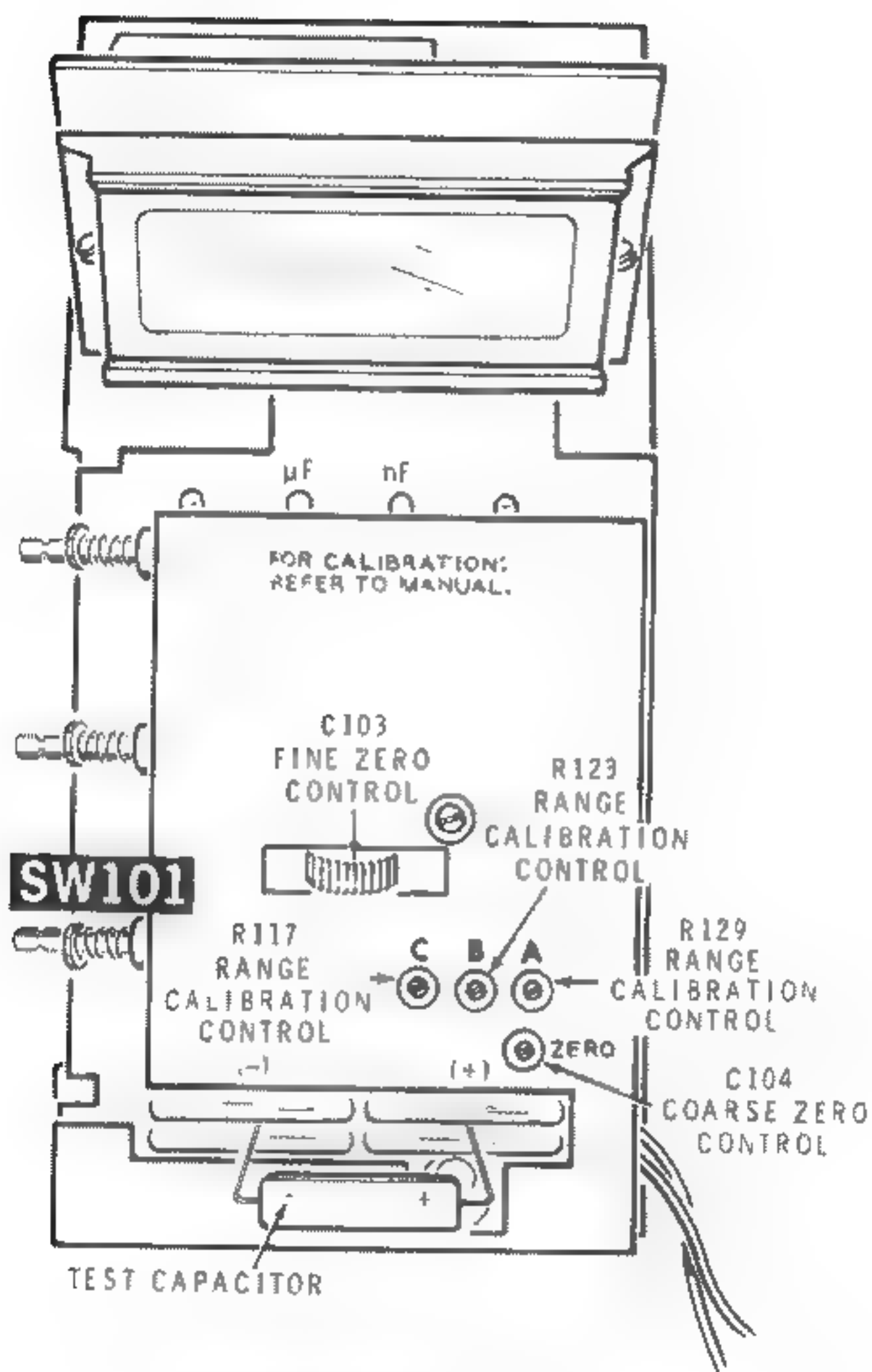




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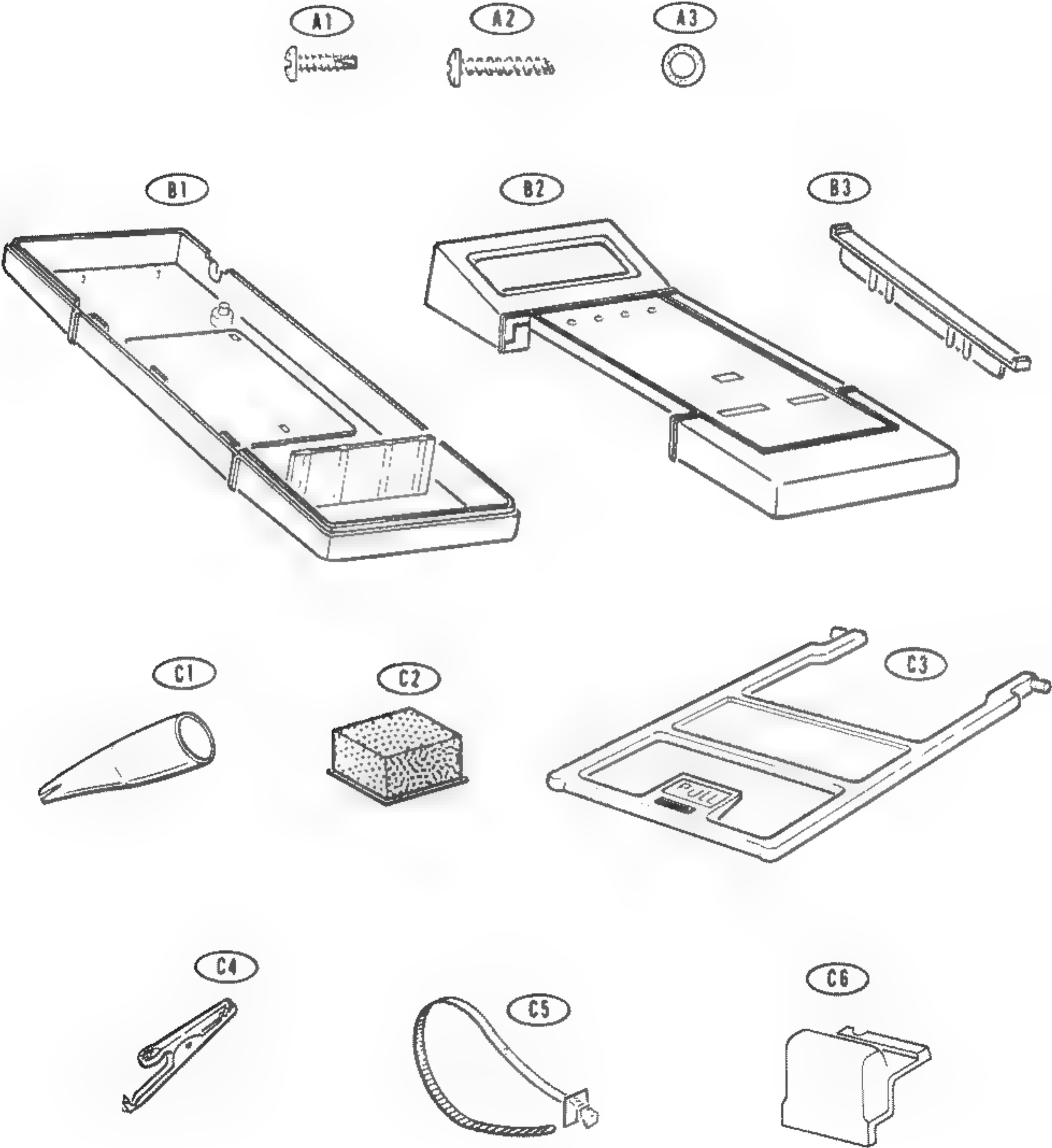


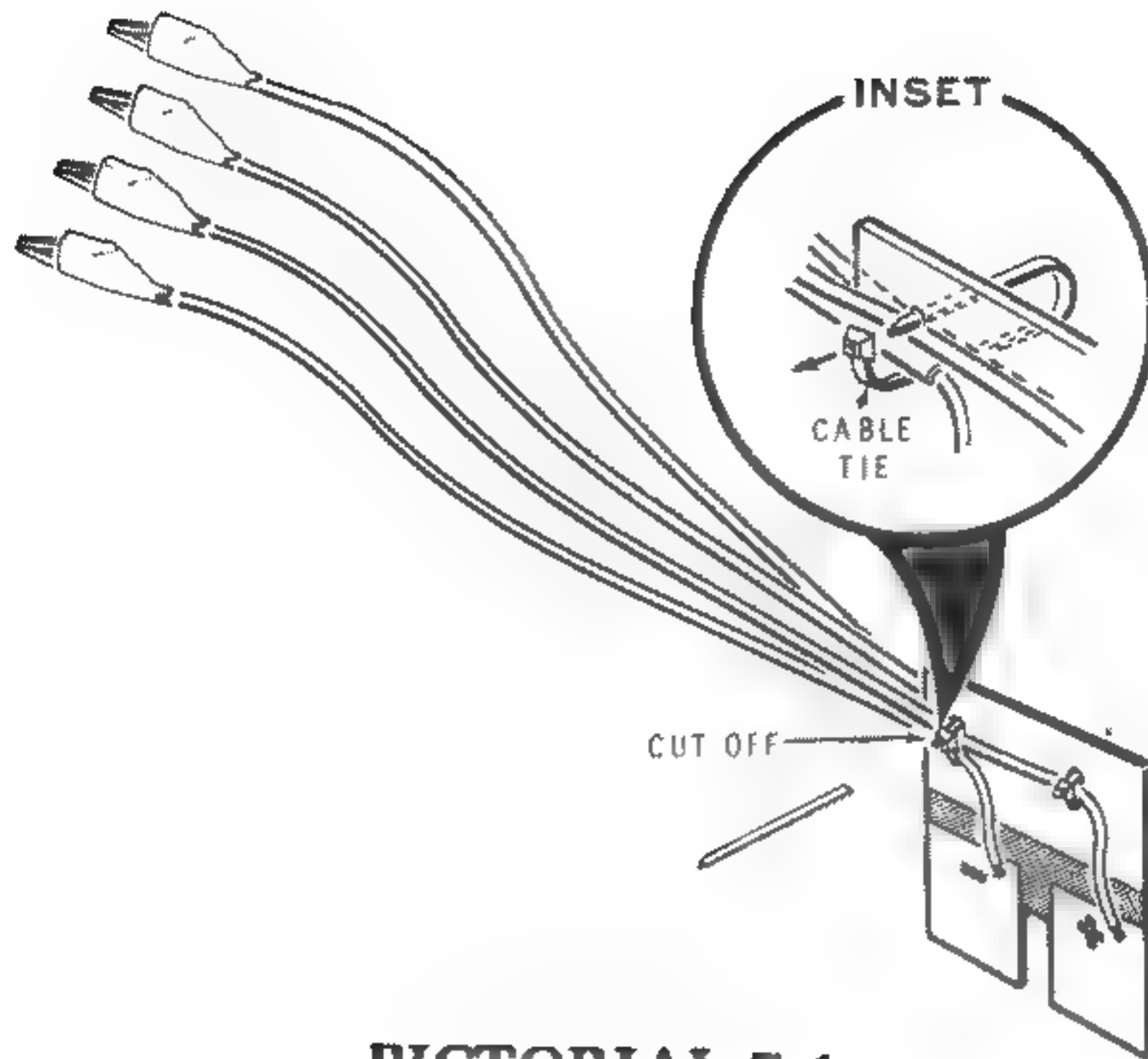
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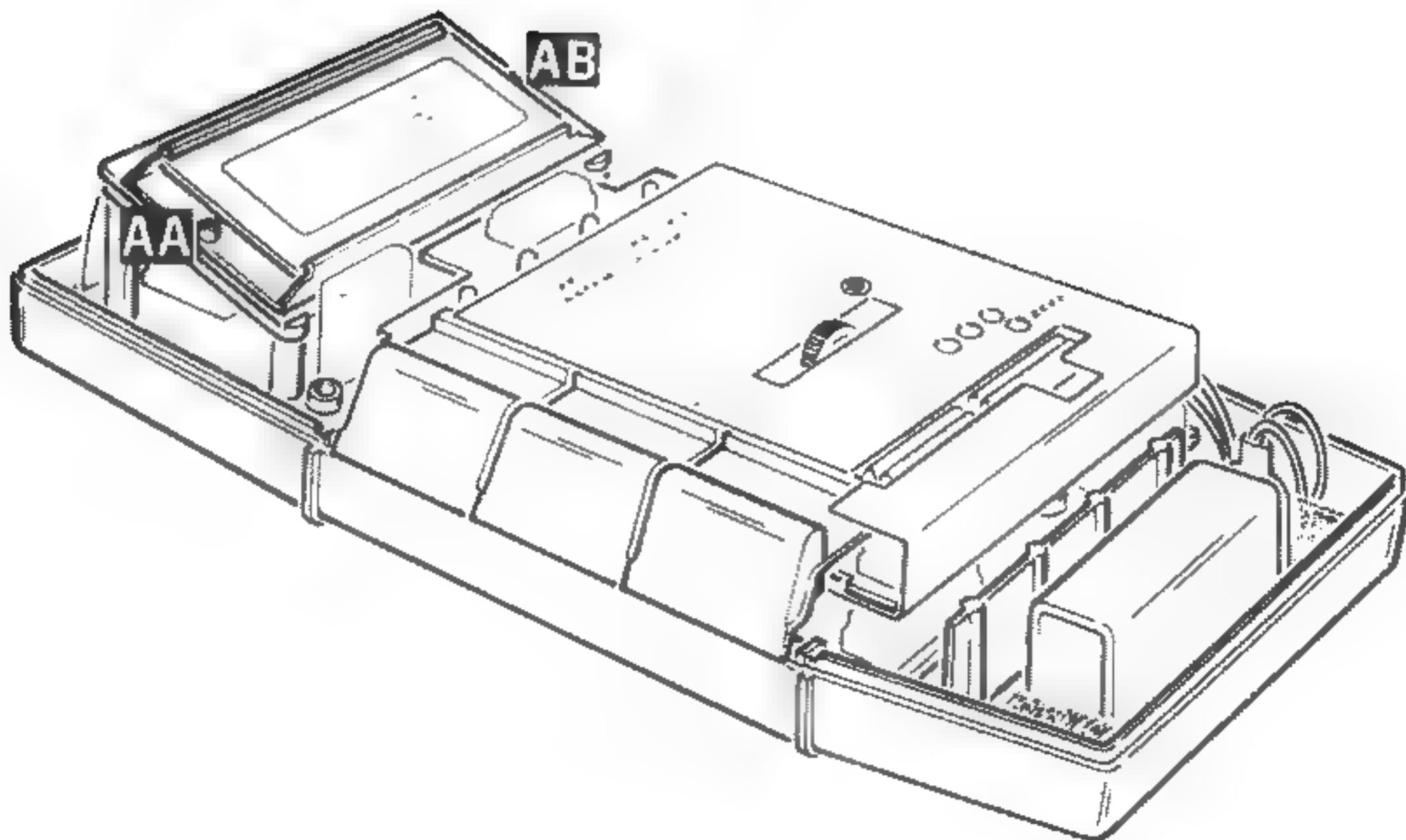
PICTORIAL 6-2

FINAL ASSEMBLY PARTS PICTORIAL

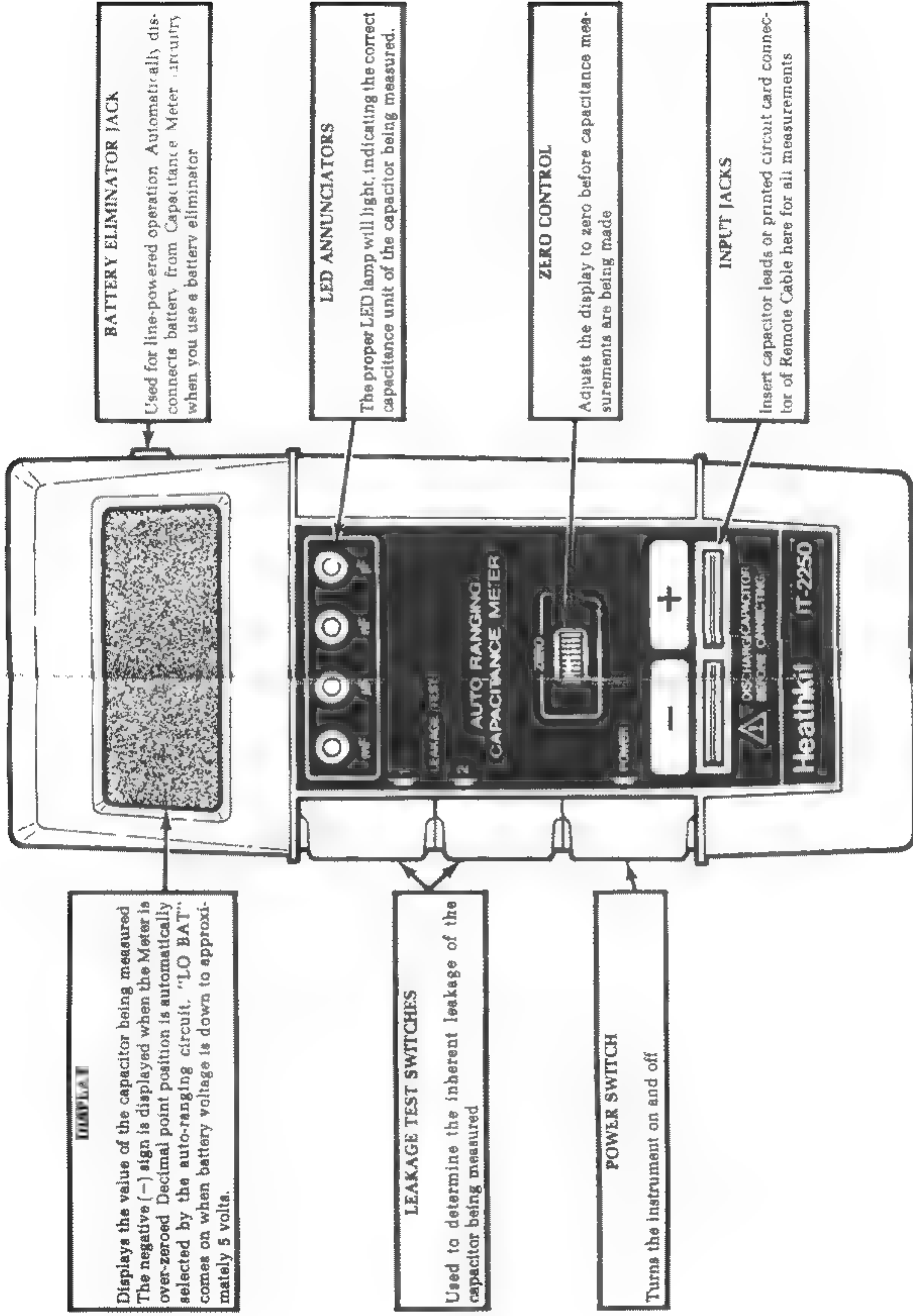




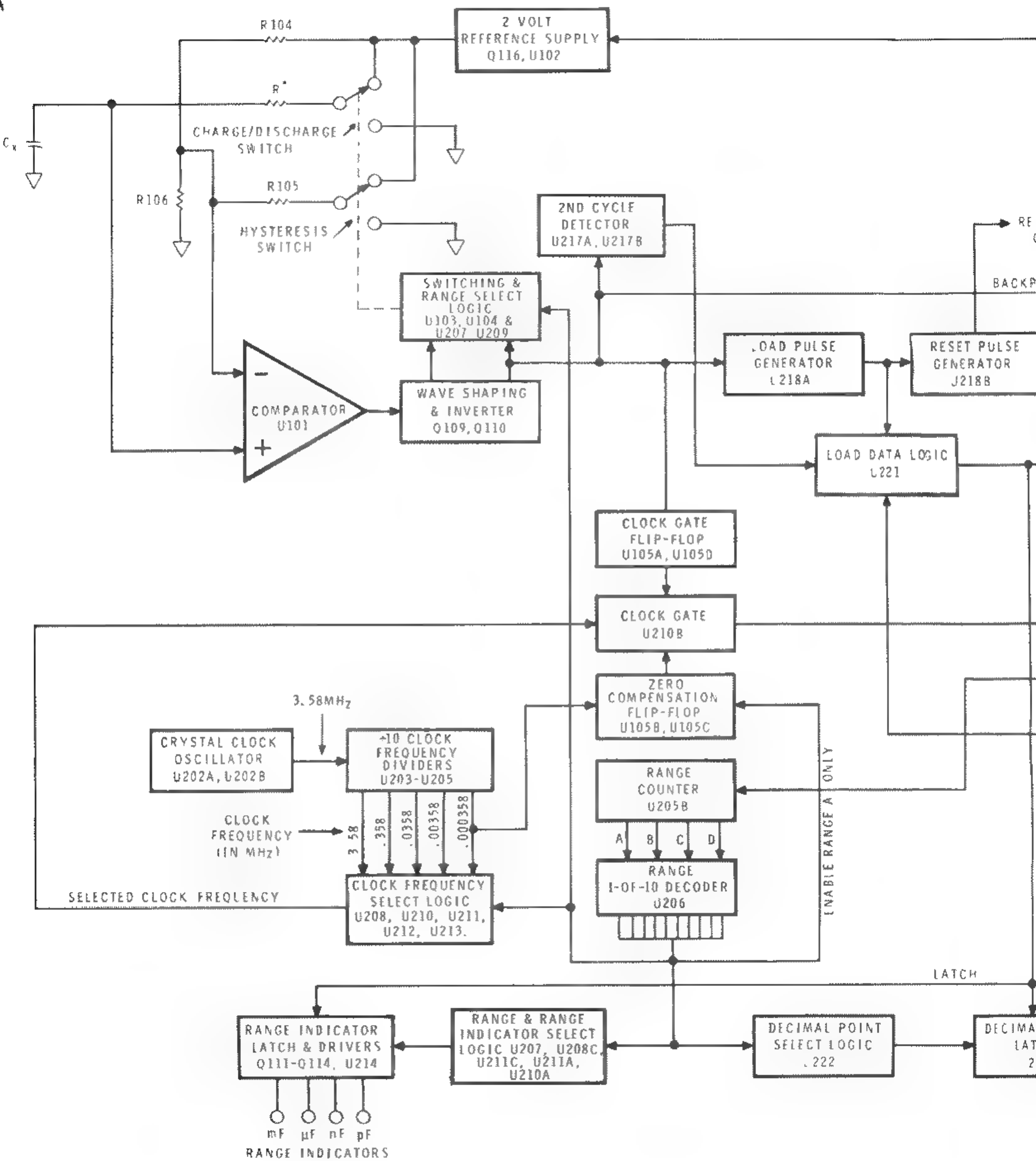
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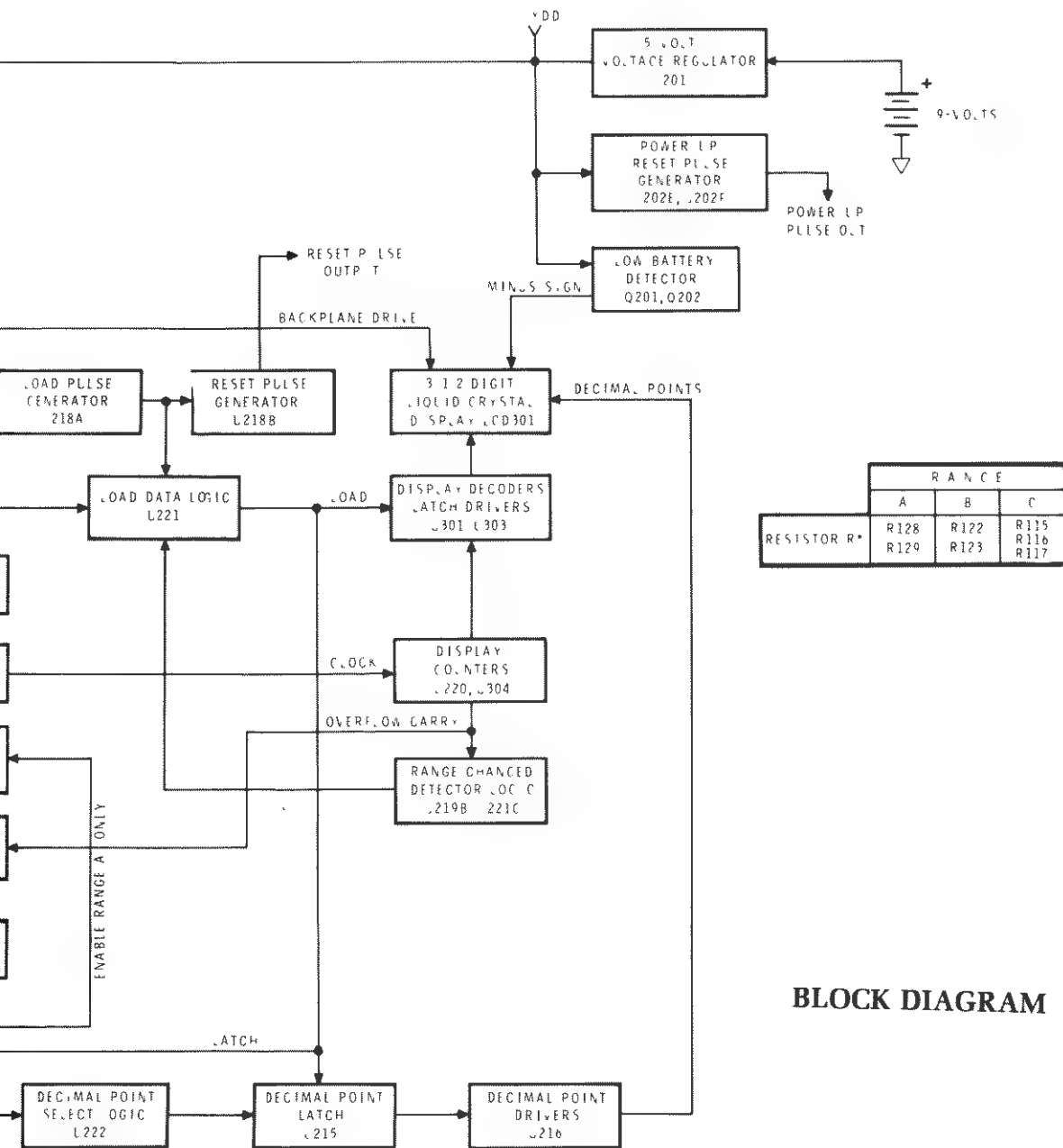


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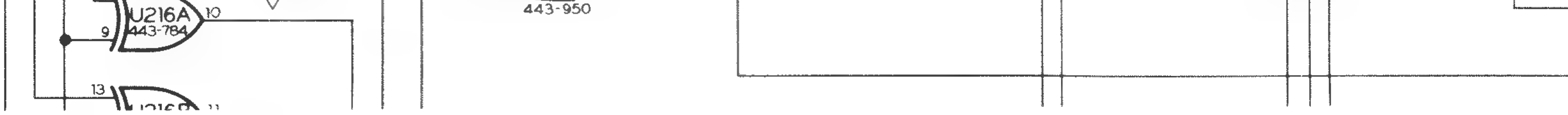
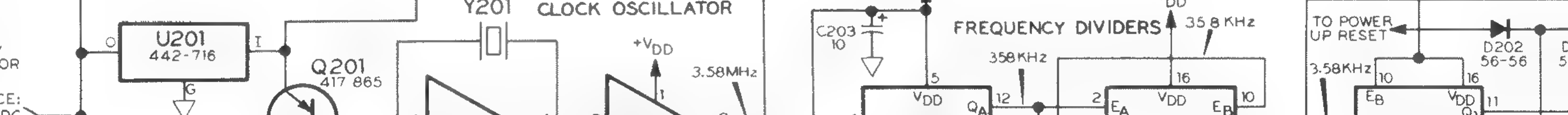
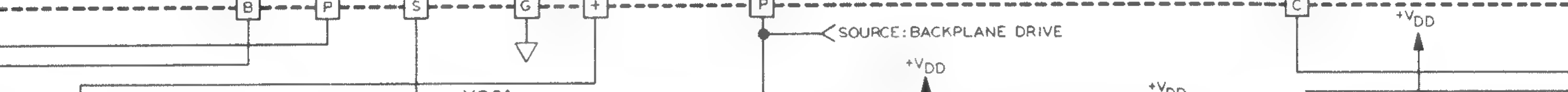
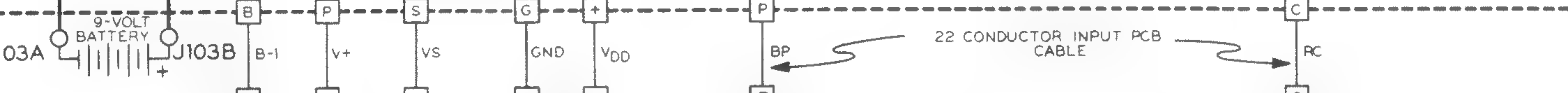
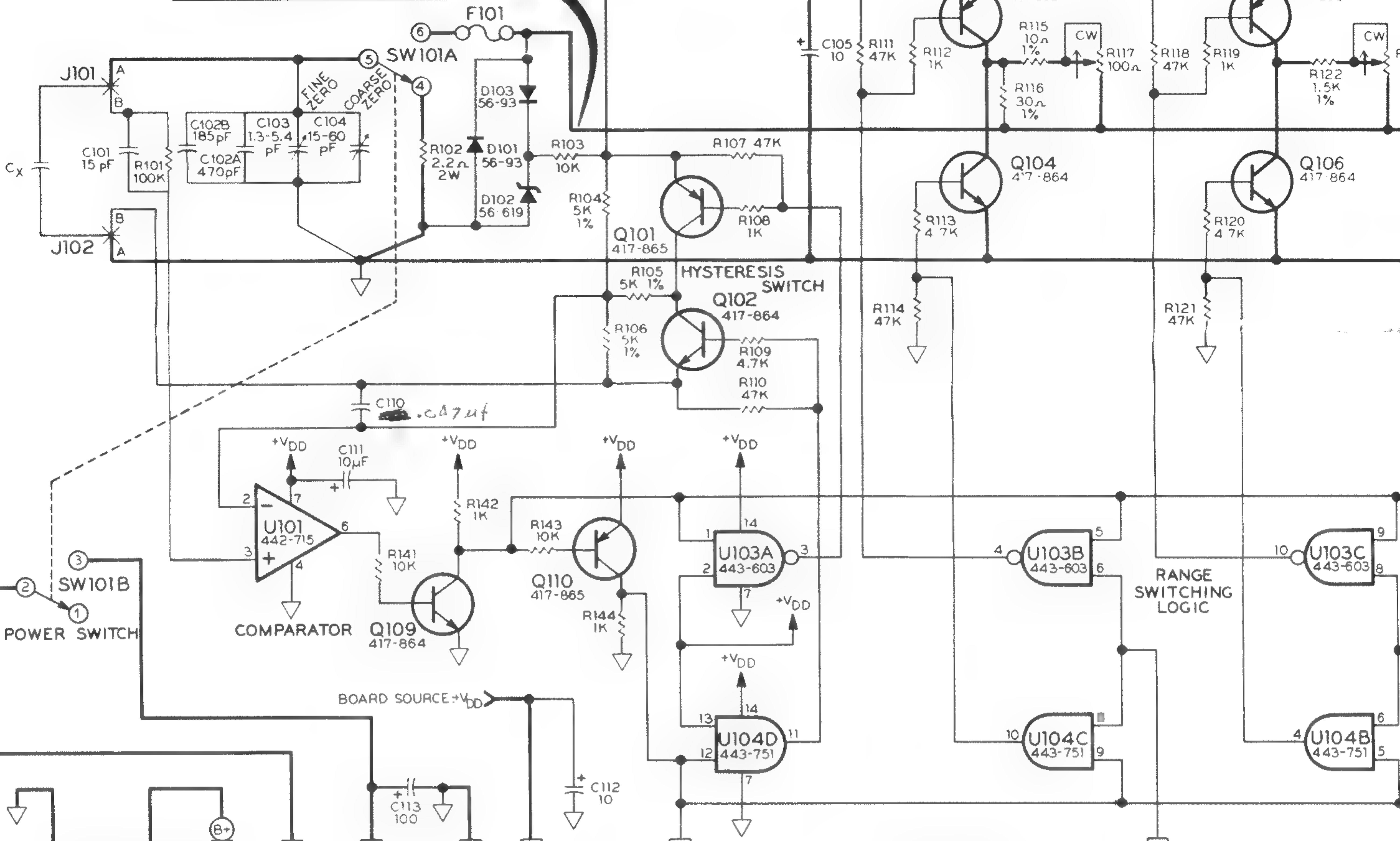
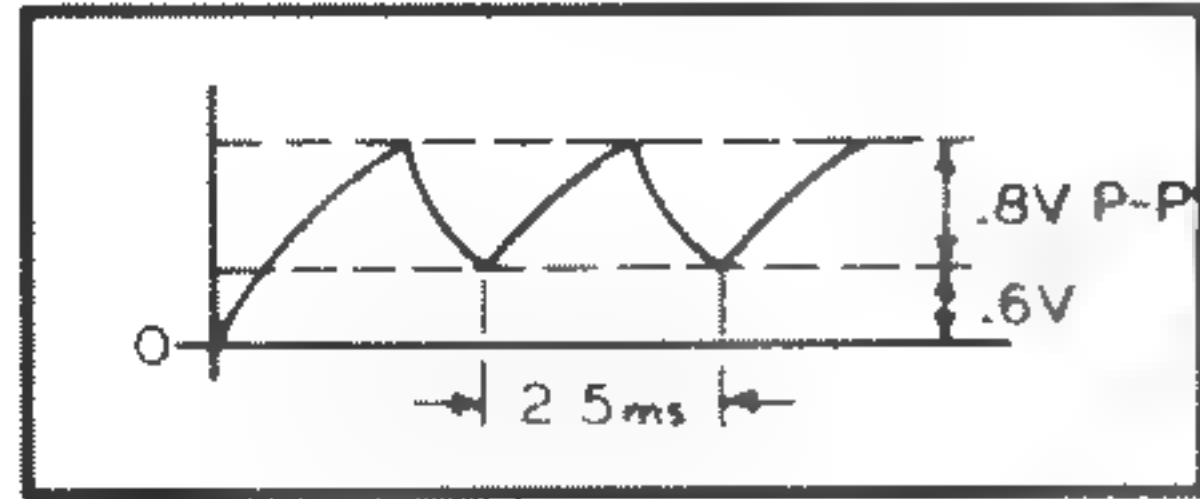
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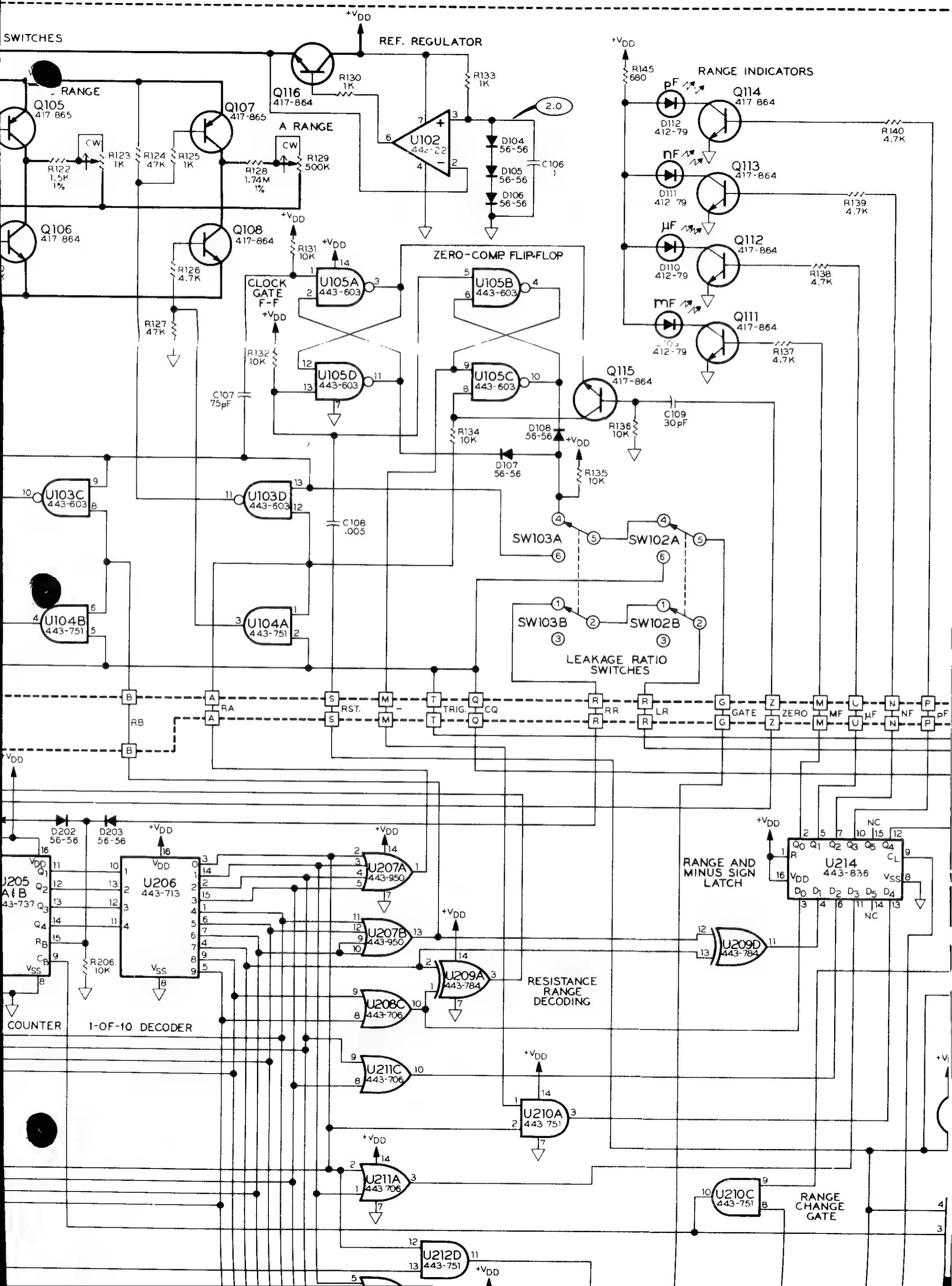




INPUT CIRCUIT BOARD

CHARGE-DISCHARGE SWITCHES





INDICATORS

114
17-864113
17-864112
17-864111
17-864110
17-864109
17-864108
17-864

DISPLAY CIRCUIT BOARD

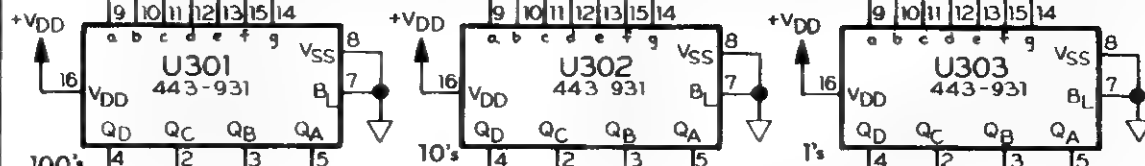
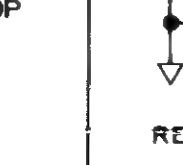
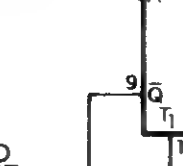
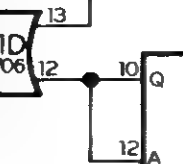
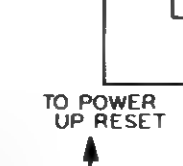
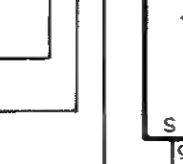
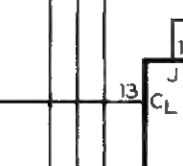
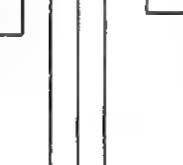
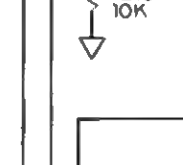
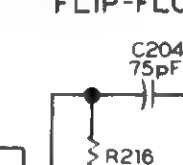
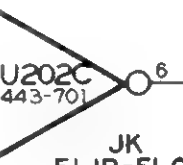
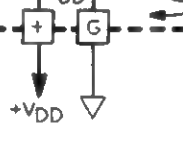
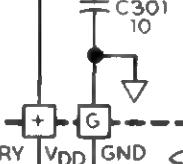
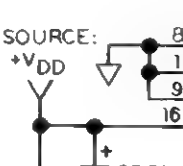
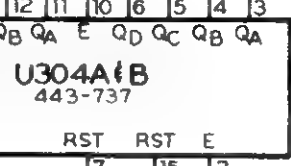
NOTE:
PINS 28/
39 TIED TO
PIN 1.

LO BATT

LCD 301

BP MINUS 1K DP-3 100-e 100-d 100-c DP-2 10-e 10-d 10-c DP-1 1-e 1-c 1-b 1-a 1-f 1-g 10-b 10-f 10-g COLON 100-b 100-a 100-f 100-g LO BATT PLUS

DISPLAY INTERCONNECTIONS

DECODERS,
LATCHES,
DRIVERSDUAL BCD
COUNTER
(10's & 100's)

DECIMAL
POINT
AND
1K
DISPLAY
DRIVERS

AND
1K LATCH

U215
443-836

NC 15 Q5 VSS C_L 9

U216A
443-784

U216B
443-784

U216C
443-784

U216D
443-784

U209C
443-784

BP

LO-BATT

DP-3

DP-2

DP-1

1K-0

LOAD

1K

+V_{DD}

U222A
443-950

U222B
443-950

DECIMAL POINT
DECODING

MAIN CIRCUIT BOARD

POWER-UP RESET

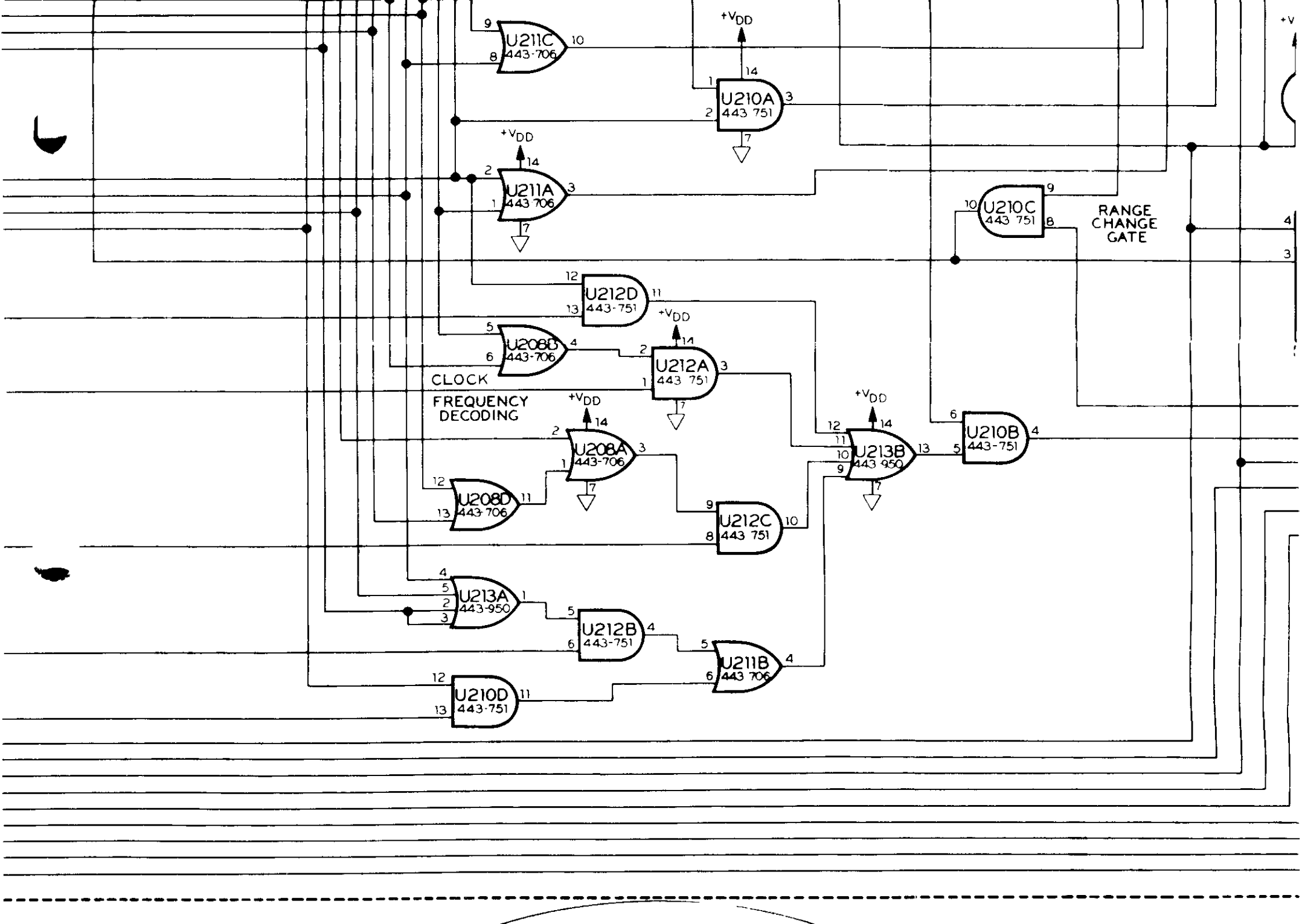
+V_{DD}
R205
1M
C202
.1

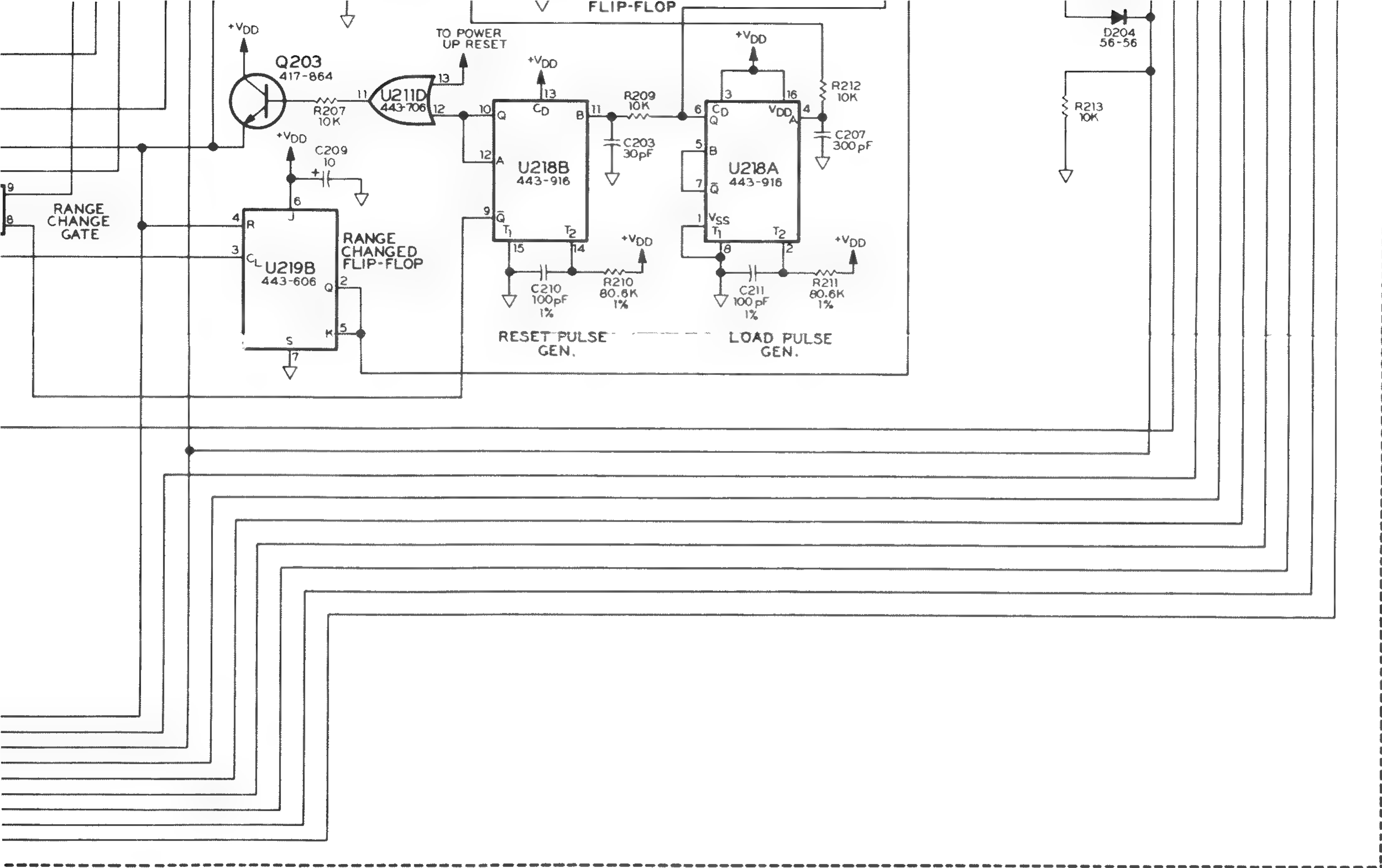
U202E
443-701

D201
56-56

U202F
443-701

SOURCE: POWER-UP RESET








Legend :

SCHEMATIC OF THE HEATHKIT® AUTO-RANGING DIGITAL CAPACITANCE METER MODEL IT-2250

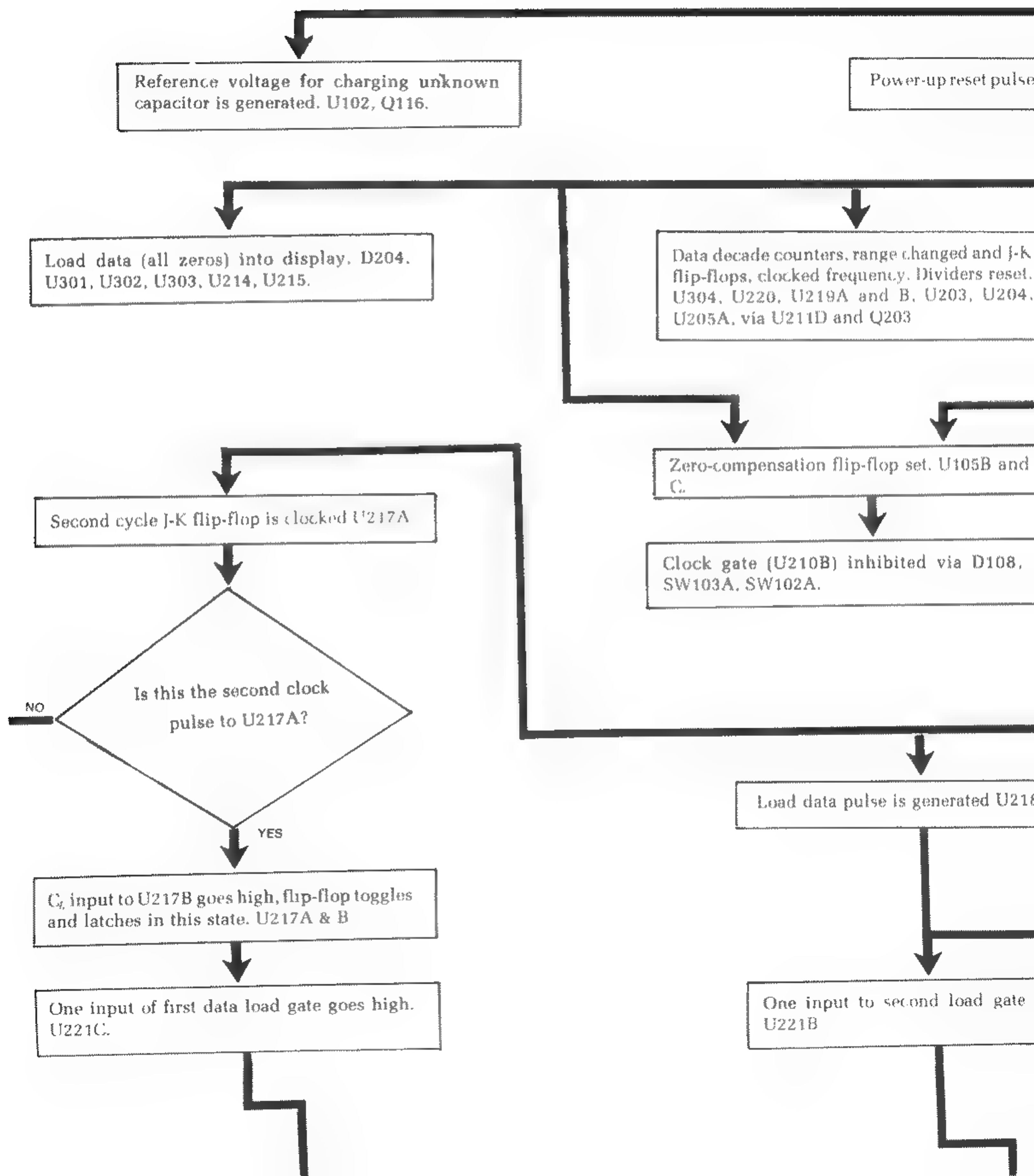
NOTES:

1. REFER TO THE "CIRCUIT BOARD X-RAY VIEWS" FOR THE PHYSICAL LOCATION OF PARTS.
2. REFER TO THE COMPONENT IDENTIFICATION SECTION IN THE VARIOUS PARTS LISTS FOR THE TOLERANCE, WATTAGE, AND TEMPERATURE COEFFICIENT OF RESISTORS SHOWN ON THE SCHEMATIC.
3. RESISTOR VALUES ARE IN OHMS (k=1000, M=1,000,000).
4. CAPACITOR VALUES ARE IN μF UNLESS OTHERWISE SPECIFIED.
5.  INDICATES CIRCUIT BOARD GROUND.
6.  INDICATES A WIRE CONNECTION TO A CIRCUIT BOARD.
7.  INDICATES A DC VOLTAGE TAKEN WITH A HIGH INPUT IMPEDANCE (10 M Ω TYPICAL) VOLTMETER FROM THE POINT INDICATED TO CIRCUIT BOARD GROUND.
8. ALL WAVEFORMS WERE MEASURED AT NOMINAL BATTERY VOLTAGE (9V) WITH LOW-CAPACITANCE, 10 M Ω PROBE. LEVELS MAY VARY $\pm 10\%$.

WAVEFORM TABLE

TEST POINT*	WAVEFORMS
UNKNOWN CAPACITOR VOLTAGE	<p>REF. VOLTAGE V₂ 1/2 REF. VOLTAGE V₁</p> <p>t₁ t₂ t₃ NON SYMMETRY DUE TO SCOPE PROBE SHUNT RESISTANCE.</p> <p>t₁ = INITIAL BIAS CHARGE. t₂ = DISCHARGE CYCLE = 1ms. t₃ = CHARGE CYCLE = 1.6ms t₂ + t₃ = MEASUREMENT CYCLE = 2.6ms.</p>
COMPARATOR OUTPUT U101 PIN 6	<p>V_{DD} = 5V 0</p> <p>t = 0 AT POWER UP</p> <p>t_m = 1st MEASUREMENT CYCLE</p> <p>t_c = COMPARATOR OUTPUT GOES HIGH.</p>
LOAD PULSE GENERATOR U218A PIN 6	<p>0</p> <p>t_c</p> <p>t_c COMPARATOR OUTPUT GOES HIGH.</p> <p>t₄ t₅</p> <p>t₄ = TRIGGER DELAY = 3μs. t₅ = PULSE WIDTH = 15μs.</p> <p>EXPANDED TIME BASE</p>
RESET PULSE GENERATOR U218 PIN 10, 12	<p>0</p> <p>t_c</p> <p>t₆ t₇</p> <p>t₆ = DELAY = 1μs. t₇ = PULSE WIDTH = 15μs.</p> <p>EXPANDED TIME BASE</p>
CLOCK GATE FLIP-FLOP U105 A & D PIN 11	<p>0</p> <p>t_c</p> <p>CLOCK GATE INHIBITED</p> <p>t₈</p> <p>t₈ = DATA UPDATE AND LOGIC RESET PERIOD = LOAD + RESET PULSES + DELAYS = 35μs.</p> <p>EXPANDED TIME BASE</p>
ZERO COMPENSATION FLIP-FLOP U105 B & C, PIN 10	<p>0</p> <p>MUST BE LOW FROM END OF RESET TO INSIDE NEXT LOAD PULSE FOR ZERO COUNT.</p> <p>t₉ t₁₀</p> <p>t₁₀ TO t₉ OF NEXT CYCLE IS LOW TO BLOCK COUNTS DURING ZERO COMPENSATION</p>
POWER-UP RESET PULSE U202, PIN 12	<p>0</p> <p>60 μs. TYPICAL</p>

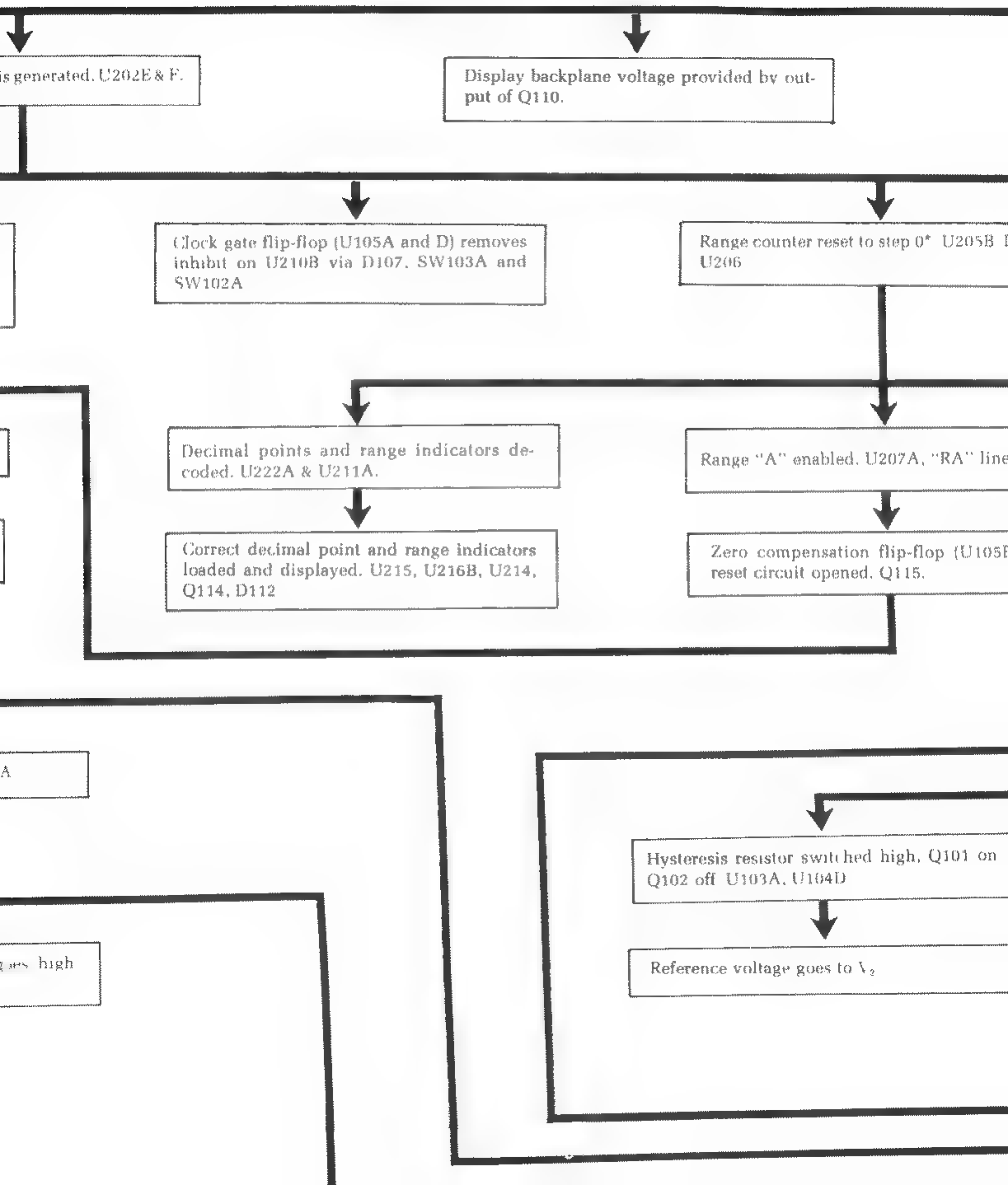
* AS VIEWED TO COMMON GROUND, 10 MEG. INPUT SCOPE PROBE, NO CAPACITOR INSTALLED (pF RANGE, READING LESS THAN 100 pF).



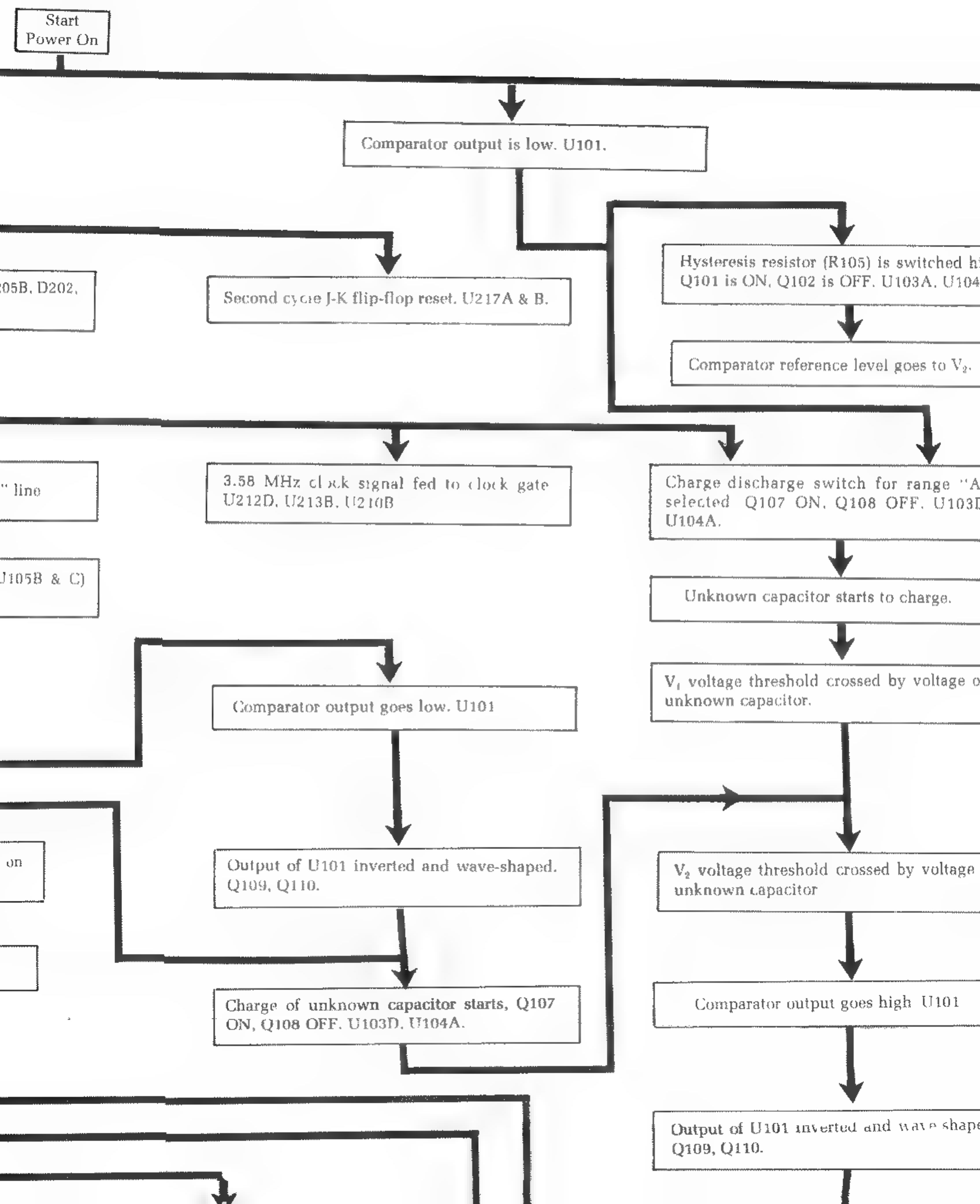
OPERATIONAL I

(Refer to the Schematic Di

Po



tic Diagram when you use this chart.)



Clock Oscillator starts. Frequency dividers provide 3.58 MHz, 358 kHz, 35.8 kHz, 3.58 kHz, 358 Hz. U202A & B, U203, U204A, U204B, U205A

Zero time-out pulse generated after delay for corresponding capacitance time. U205A

Zero-compensation flip-flop is reset. U105B & C.

Inhibit removed from clock gate. D108, SW103A, SW102A, U210B.

Data counters start counting selected clock freq. U220, U304.

Does count exceed 1999?
U219A

YES

Clock signal applied to range counter clock gate U210C.

Power supply regulator provides 5 VDC to all circuits. U201.

Is battery voltage greater than 5 V?

NO

YES

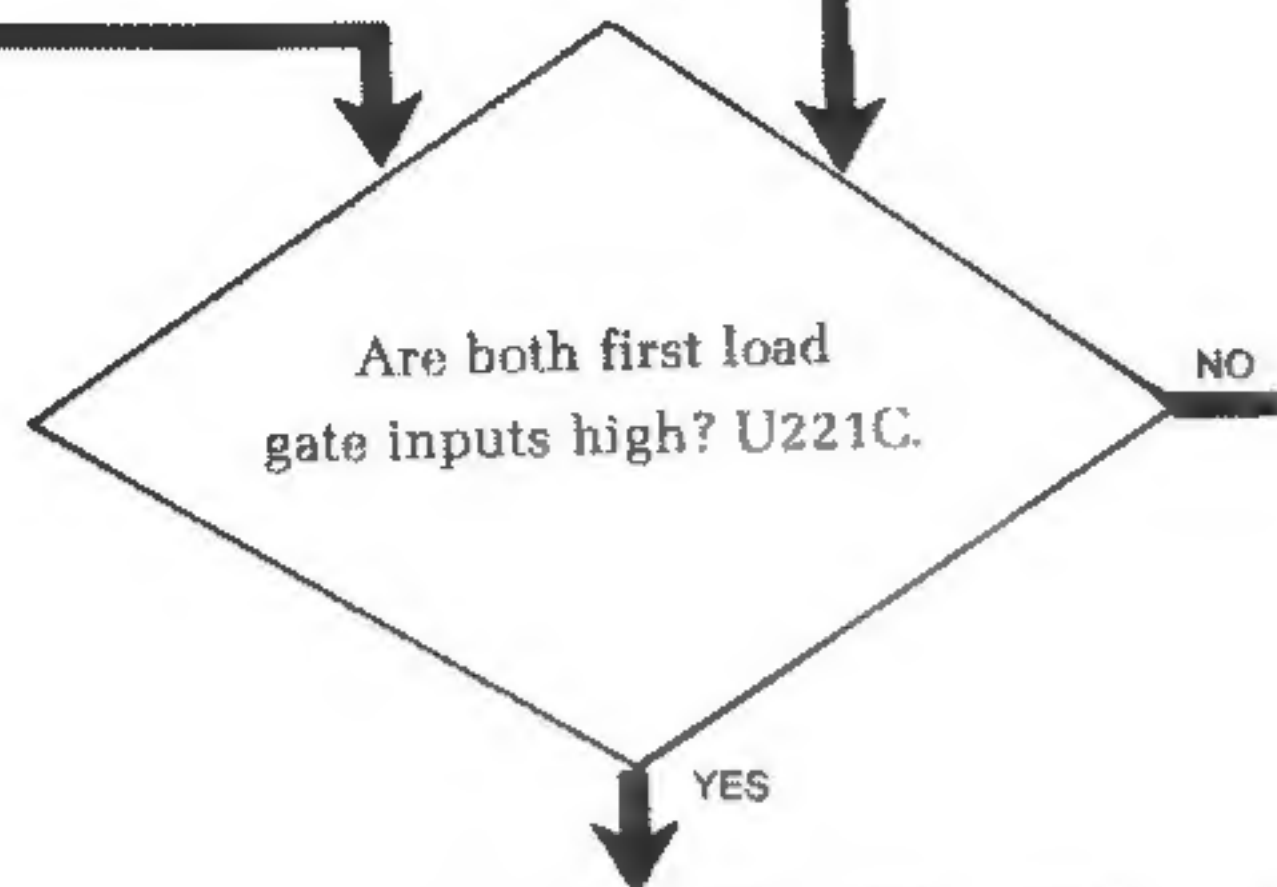
Turn on "LO BAT" indicator. Q201, Q202, U215, U209C (on next data load pulse).

Hysteresis resistor (R105) switched low, Q101 OFF, Q102 ON. U103A, U104D.

Reference voltage drops to V_1 .

Clock gate flip-flop (U105A & D) removes inhibit on U210B, via D107, SW103A, SW102A

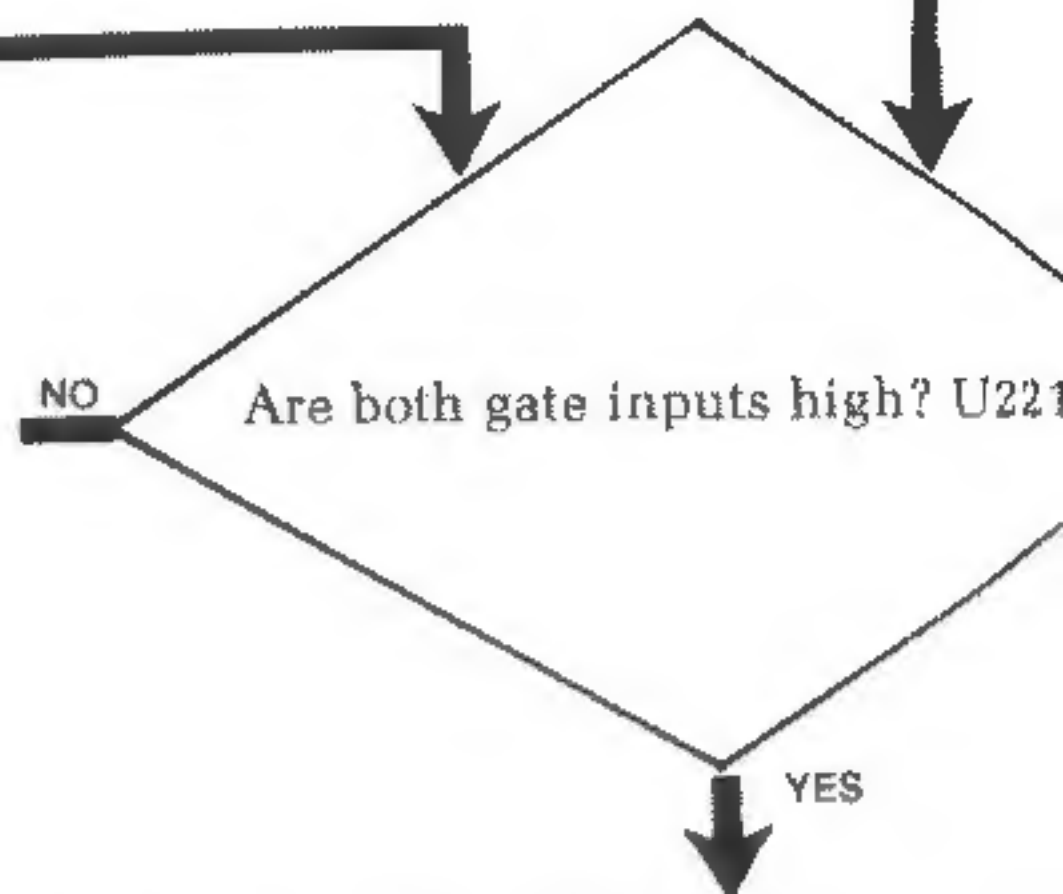
Has zero compensation flip-flop (U105 B & C) been reset?



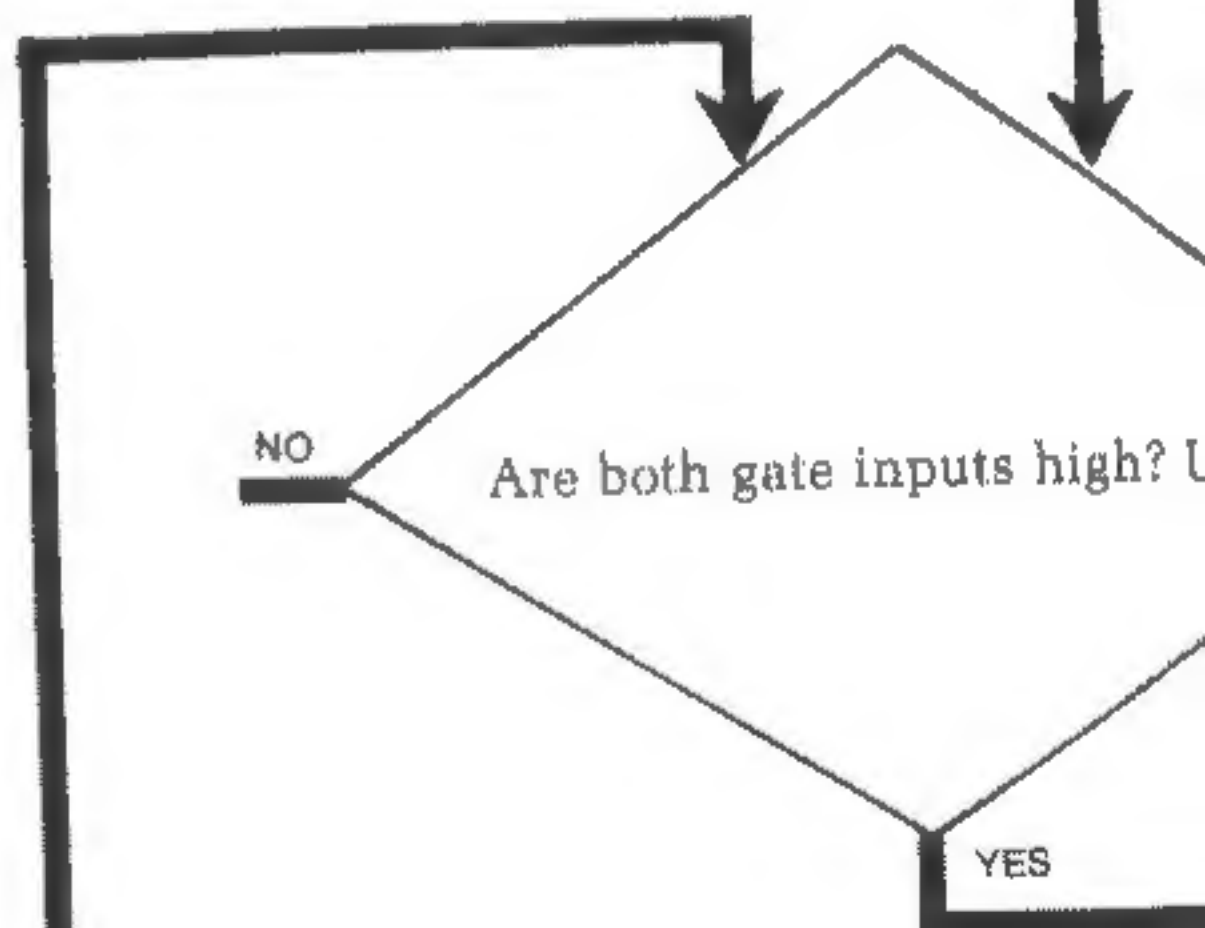
Gate output goes high. U221C.

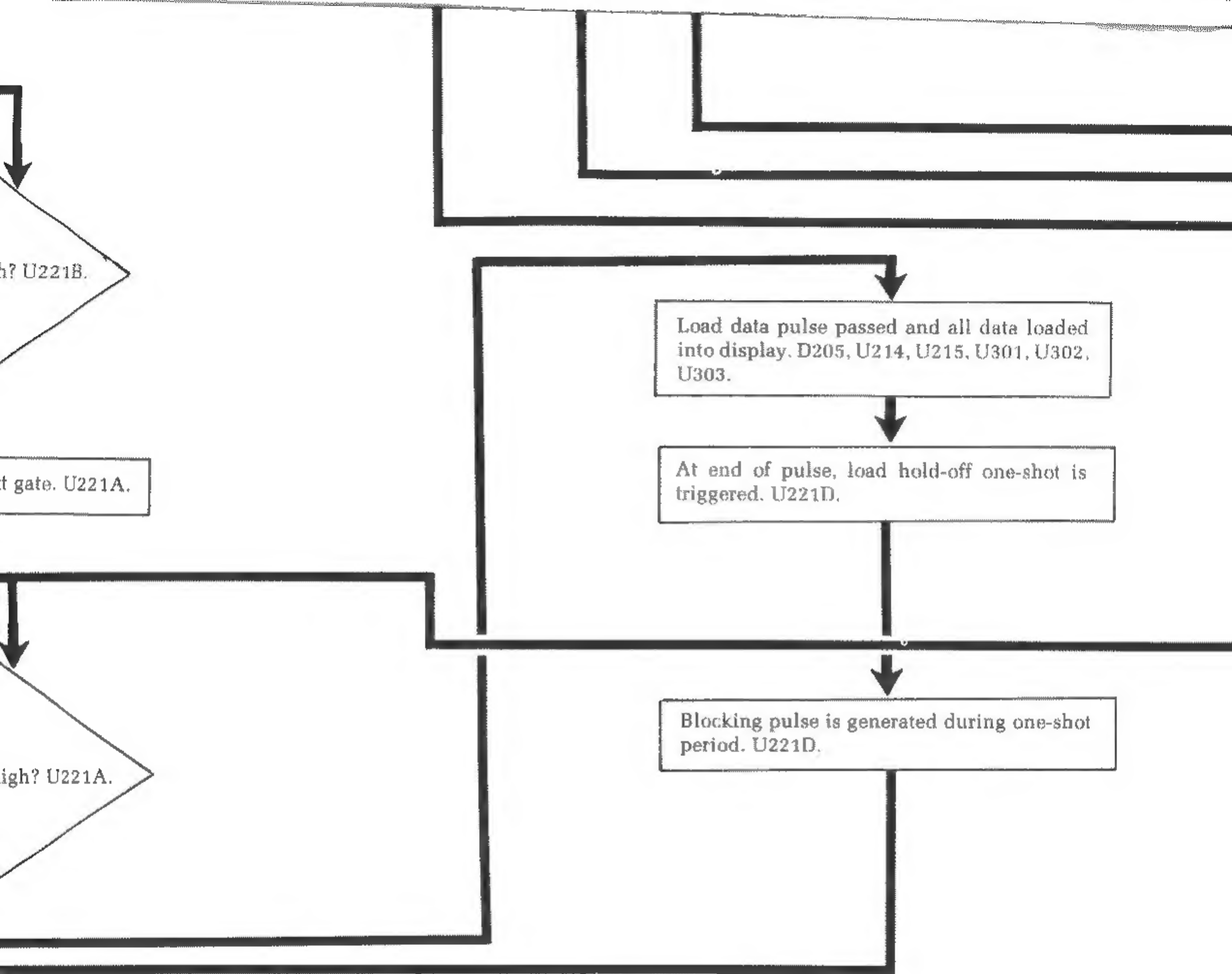
Range changed J-K flip-flop is toggled and latched. U219B.

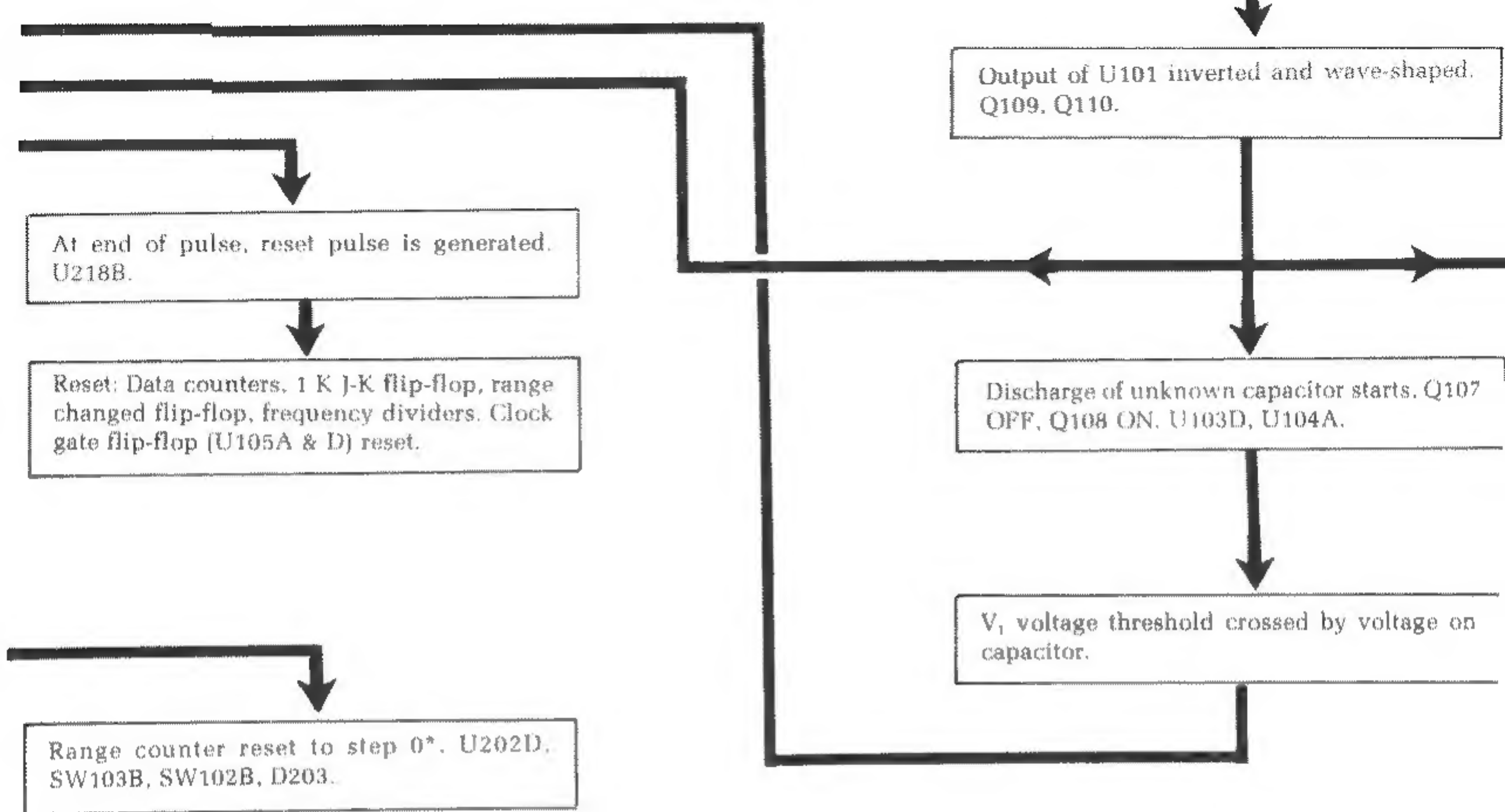
Block first latch gate. U221C.

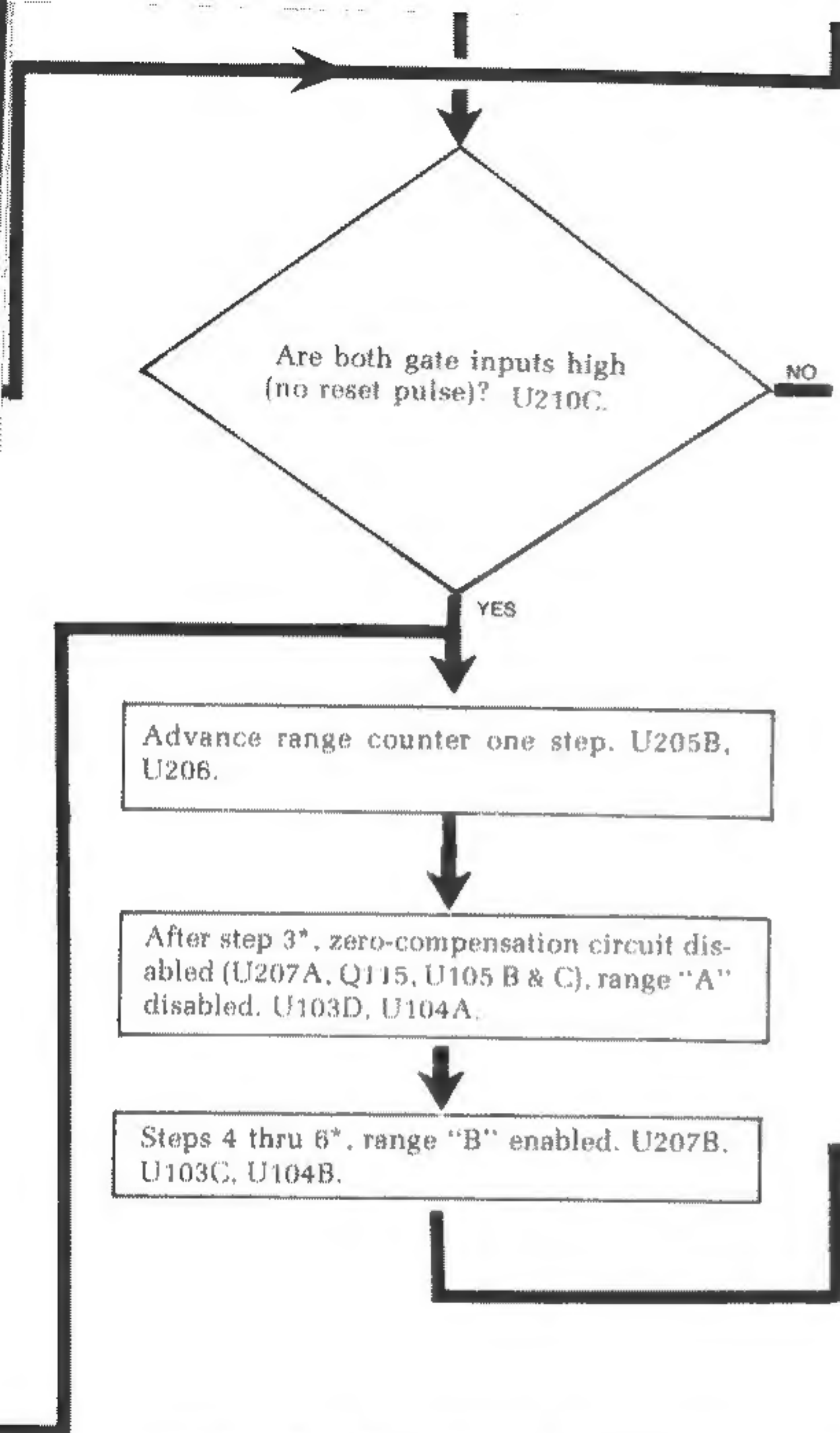


Load data pulse passed to next gate.

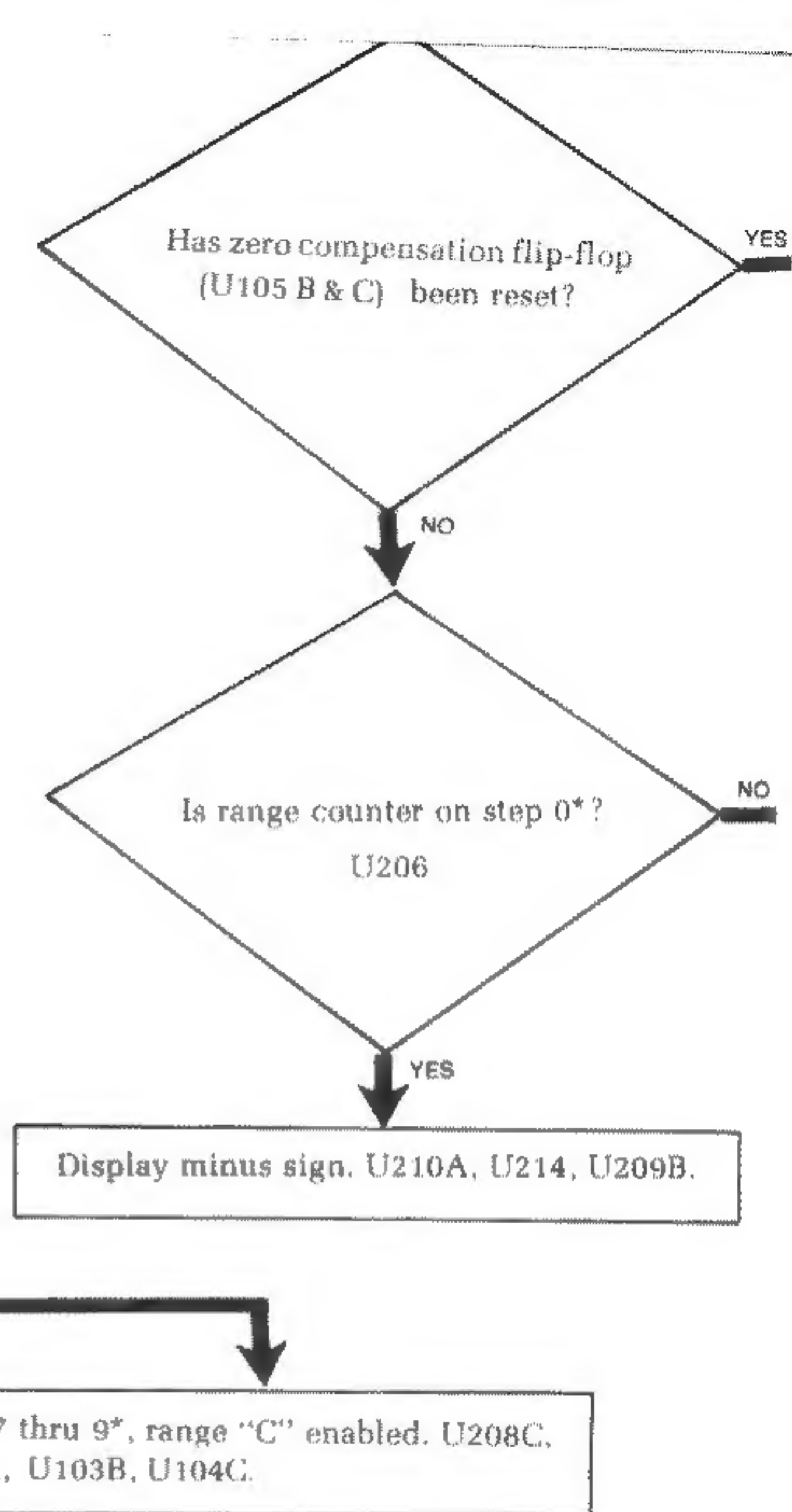








* See "Appendix" on Page 77 in the Manual for reference to step numbers.



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